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FINAL REPORT

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COMPREHENSIVE ECONOMIC COST STUDY OF AIR POLLUTION CONTROL COSTS FOR SELECTED INDUSTRIES AND SELECTED REGIONS

by

M.E. Fogel, D.R. Johnston, R.L. Collins,
D.A. LeSourd, R.W. Gerstle, E.L. Hill

Prepared for:

National Air Pollution Control Administration
Consumer Protection and Environmental Health Service
Public Health Service
Department of Health, Education, and Welfare

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RESEARCH TRIANGLE INSTITUTE
OPERATIONS RESEARCH AND ECONOMICS DIVISION
RESEARCH TRIANGLE PARK, NORTH CAROLINA

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ABSTRACT

Estimates were made of the costs of controlling the emissions of selected pollutants from twenty-two sources within 100 metropolitan areas. Under the implementation plan assumed, these costs will be incurred during the period of Fiscal Year 1970 through Fiscal Year 1975. The pollutants selected are particulates, sulfur oxides, hydrocarbons, and carbon monoxide. The emission standards applied are considered stringent in comparison with many currently in use throughout the Nation. The sources for which control cost estimates were made are solid waste disposal, steam-electric generating plants, industrial boilers, commercial and institutional heating plants, residential heating plants, and the following industrial categories: kraft pulp, iron and steel, gray iron foundry, primary nonferrous metallurgical (copper, lead, zinc, and aluminum), sulfuric acid, phosphate fertilizer, petroleum refining, cement, lime, coal cleaning, petroleum products and storage, grain milling (animal feed) and handling, varnish, rubber (tires and inner tubes), and secondary nonferrous metallurgical (copper, lead, zinc, and aluminum). Essential data defining regional and relevant process and air pollution control engineering characteristics required to support the cost analyses for each source are presented and analyzed in separate appendixes to the report.

The coking, plastics, rendering, and soap and detergent industries were examined; however, control cost estimates were not made.

Air pollution control costs are presented for each region and source by fiscal year in terms of investment and annual expenditures. The cost estimates developed reflect the control of sources in operation as of Calendar Year 1967 as well as additional sources assumed to be constructed during the period of Calendar Year 1968 through Fiscal Year 1975. For the sources in operation in 1967, it was assumed that compliance with the standards and hence the rate at which the estimated costs are incurred is defined by the assumed implementation plan. Control of additional sources was assumed to take place immediately. In addition, emission estimates are presented which reflect conditions both with and without implementation of the emission standards. The estimated investment costs for the 100 metropolitan areas amount to $2.64 billion; an annual cost of $1.88 billion is reached by Fiscal Year 1975. An extensive bibliography is also included.

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Chapter 1

Introduction

I. PURPOSE OF RESEARCH

This report is submitted in partial fulfillment of the requirements of National Air Pollution Control Administration (NAPCA) Contract No. CPA 22-69-79. The research results presented herein are in support of the cost estimates given in the Second Report of the Secretary of Health, Education, and Welfare to the Congress of the United States as provided for in section 305(a) of Public Law 90-148, the Clean Air Act, as Amended.

The purpose of the research reported in this document was to make estimates of the air pollution control costs that will result from implementation of the Clean Air Act, as Amended. The section of the act pertinent to this research reads:

> *Sec. 305. (a) In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal [illegible]s beginning after June 30, 1969, the Secretary, in coo[illegible]ation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including an analysis of the national requirements for and the cost of controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law. The secretary shall submit such detailed estimates and the results of such comprehensive study of cost for the five-year period beginning July 1, 1969, and the results of such other studies, to the Congress not later than January 10, 1969, and shall submit a reevaluation of such estimate and studies annually thereafter.*

II. SCOPE OF RESEARCH

Costs of control were estimated for three major categories of pollutant sources: solid waste disposal, stationary combustion, and industrial process. Included as stationary combustion sources are steam-electric generating plants, industrial boilers, commercial and institutional heating plants, and residential heating plants. Initially, the industrial process sources studied were: the kraft (sulfate) pulp, iron and steel, gray iron foundry, primary nonferrous metallurgical, sulfuric acid, phosphate fertilizer, petroleum refining, cement, lime, coal cleaning, petroleum products storage, grain milling and handling, varnish, rubber (tires and inner tubes), secondary nonferrous metallurgical, coking, plastics, and rendering industries. Of these, the coking, plastics, rendering, and soap and detergent industries were deleted from the study for reasons included in Appendixes Z, AA, BB, and CC.

The pollutants for which control costs were estimated (as appropriate to each particular source) were particulates, sulfur oxides, hydrocarbons, and carbon monoxide.[1/]

Costs of control were estimated for establishments of the selected source categories that operated during 1967 in 100 metropolitan areas of the Nation that were selected and defined by NAPCA. Both investment and annualized costs for the affected areas were estimated and expected error limits were assigned to all cost estimates.

Additionally, emission control costs that might be incurred by facilities built during the period 1968 through Fiscal Year 1975 were estimated. These estimates are limited to the sources and the 100 areas mentioned above. Additional costs resulting from growth were estimated for all of the 100 metropolitan areas; no estimates on an area by area basis were made.

[1/] Air quality criteria and control technology documents for particulate and sulfur oxides have been published by NAPCA; documents for hydrocarbons and carbon monoxide are in preparation.

III. LIMITATIONS

The principal and general limitations of this study are described below. Limitations peculiar to a particular source are discussed in the pertinent appendix. Estimates of numbers and sizes of sources, emissions, and costs made in this study were based entirely on data obtained from NAPCA surveys, technical and trade journals, the Bureau of the Census, government reports, and manufacturing firms and trade associations.

In a number of instances, the required data were not available in a directly usable form. In those cases and when feasible, estimates of the parameters were made and the sensitivity of the resulting cost estimate to the estimated parameter was considered. For many industries it was not possible to obtain sufficient detailed engineering data to make reliable cost estimates for all of the pollutant sources within the industry. Accordingly, cost estimates for those industries were based only on those processes considered to be prime pollutant sources. In some cases the cost of controlling emissions from materials handling could not be estimated due to the paucity of appropriate data.

To estimate costs, it was also necessary to assume a level of emission control to be achieved for each pollutant emitted from each source category. The assumed levels of control were based on emission standards selected by NAPCA and described in Appendix A. Cost estimates are for control at the levels required by the assumed standards and, of course, would be higher or lower if more or less stringent emission standards were assumed.

The area and total cost estimates presented in this report apply only to the control of particulates, sulfur oxides, hydrocarbons, and carbon monoxide. The projected costs should not, therefore, be considered the full cost of achieving clean air. There are many other pollutants and sources that must be included in the calculation of such a figure.

Finally, it should be emphasized that making cost estimates required a number of assumptions regarding control technology. In a few cases these assumptions were somewhat arbitrary and do not necessarily reflect the latest technology available. Insofar as possible, however, current techniques of proven effectiveness were assumed. It is probable that new and improved control equipment and methods will evolve during the time span of the implementation plan assumed for this analysis. Such developments, as well as unpredictable price movements, may cause actual costs to differ significantly from the estimates presented herein. Furthermore, actual control costs may include some items of expense not predicted by the simplified source descriptions assumed for this analysis.

IV. PLAN OF REPORT

The results of this research are presented in the following three chapters. Chapter 2 discusses the methodology employed to obtain estimates of the cost of controlling pollutant emissions from solid waste disposal, stationary combustion, and industrial processes in 100 metropolitan areas of the United States; Chapter 3 presents the cost estimates; and Chapter 4 outlines the emission reductions that would be accomplished by implementing the plan of control assumed herein. Appendixes to this report describe the emission standards assumed, the metropolitan areas studied, the implementation plan, the metropolitan area costs by fiscal year, and the detailed engineering and cost data, by source, used in the analyses.

Chapter 2

Study Methodology

I. INTRODUCTION

The objective of this chapter is to describe in general terms the methods and the data employed to estimate regional air pollution control costs.

The methods are described under the following section headings: "Methodology Overview," "Selection of Pollutants," "Selection of Sources," "Engineering Analysis," "Source Statistics," "Cost Analysis," and "Validity of Cost Estimates." The general descriptions presented in this chapter are supplemented by appendixes to this report which detail the procedures followed for each of the sources.

II. METHODOLOGY OVERVIEW

The method used in the cost estimations included steps common to all of the sources analyzed. First, it was necessary to determine which of the pollutants under study were being emitted in concentrations or at rates exceeding the assumed control standards. The next step was the calculation of 1967 emissions, based on an estimate of the level of control in effect at that time. This established a baseline for subsequent control-cost analyses. Assuming such a baseline, calculations were performed to determine the pollutant removal efficiencies required to bring 1967 emissions into compliance with the emission standards assumed. Control equipment and/or other control procedures that would achieve the calculated pollutant removal efficiency were identified. Cost estimates based on the control procedures identified were then made for each category of polluting source segregated by area; the accompanying reduction in emissions was also calculated.

A special series of calculations to account for the control of additional capacity constructed after 1967 was also performed. The emissions and resulting control costs for the sources existing in 1967 were computed and tabulated by area according to the implementation schedules assumed. The costs of controlling the sources assumed to be constructed after 1967 were computed assuming that control takes place in the same year the facility is constructed. The additional sources were given credit for a control level, without the act in effect, equal to the source average in 1967. Costs for controlling the additional sources were calculated only as a single quantity for all the 100 areas.

III. SELECTION OF POLLUTANTS

Of the many pollutants for which control expenditures may eventually be required, only four were selected by NAPCA for this study. They are particulates, sulfur oxides, hydrocarbons, and carbon monoxide. Choice of these particular pollutants was based on two important considerations. First, and most important, these pollutants are significant because of their widespread and adverse effects on communities. Second, acceptable emission control techniques exist for these four pollutants. In fact, air quality criteria and control technology documents for particulate and sulfur oxides have already been published by NAPCA; hydrocarbon and carbon monoxide documents will be published in early 1970.

IV. SELECTION OF SOURCES

The sources selected for inclusion in this study are those that emit particulates, sulfur oxides, hydrocarbons, or carbon monoxide in appreciable quantities. Initially, the sources selected by NAPCA included steam-electric generating plants, industrial boilers, commercial-institutional heating plants, residential heating plants, the grain milling and handling, rendering, kraft (sulfate) pulp, sulfuric acid, soap and detergent, phosphate fertilizer, petroleum refining, asphalt batching, cement, lime, iron and steel, gray iron foundry, primary nonferrous metallurgical, and secondary nonferrous metallurgical industries, and solid waste disposal. Discussions with RTI personnel led to the addition of the plastics, varnish, coking, rubber (tires and inner tubes), petroleum products storage, and coal cleaning industries to the list of sources. Subsequently, as was indicated in Chapter 1, the coking, plastics, rendering, and soap and detergent industries were deleted from the list for reasons cited in Appendixes Z, AA, BB, and CC.

V. ENGINEERING ANALYSIS

A. Source Analysis

Before cost analysis could be performed, a thorough engineering analysis of the sources was necessary. This involved an understanding of production processes and an appraisal of their emissions, existing levels of control, and other factors related to air pollution control and control costs. In addition, there were numerous process steps for which one or more unit processes could be employed, e.g., wet or dry calcining of cement.

B. Emission Estimates

For each unit process, emission factors were either obtained from published literature or derived. Discussions of the emission factors employed for specific sources are presented in the appropriate appendixes. Uncontrolled emissions were estimated for the unit processes simply by multiplying emission factors by appropriate production estimates. Estimates for a given source were made on hourly, daily, or yearly bases for a given plant, an area, or the entire Nation.

C. Level of Control Estimates

To ascertain whether the 1967 emissions from a given source were in compliance with the assumed standards,[1/] it was necessary to determine the existing level of control. Ideally, the level of control should be determined for each source within each metropolitan area. However, it became apparent early in the project that area-specific information could not be obtained during the available time, if at all. Accordingly,

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[1/] These standards are discussed in detail in Appendix A.

estimates of 1967 control levels were based on the best obtainable secondary data.[2] For some sources, average control levels for the Nation were applied to the sources in all metropolitan areas.

In some cases where emissions were being controlled, the control system was actually part of the production process; such costs were not considered to be air pollution control expenses.

D. Required Removal Efficiency

The next step in the analysis was the calculation of the pollutant removal efficiencies required to satisfy the emission standards assumed.[3] Given the allowable and the existing emissions, the required removal efficiency was calculated using the following equation:

$$R.E. = \frac{Qe - Qa}{Qe} \times 100\%$$

where: R.E. is the removal efficiency (in percentage) required;

Qe is the existing emission; and

Qa is the allowable emission.

This relationship holds for both concentration-based and mass rate emission standards. The New York State Standard was used for solid waste incinerators. This standard relates the allowable particulate emissions in pounds per hour to the pounds per hour of refuse charged. In the case of stationary combustion equipment, the State of Maryland Standard was used. This standard states the allowable particulate emission, in terms of pounds per million Btu input, as a function of the equipment capacity rating in millions of Btu per hour. The standard also provides for previously existing and new installations, with more stringent requirements for new installations. A standard of 1.46 pounds of sulfur dioxide per million Btu input was used for sulfur oxide emissions from stationary combustion equipment; this corresponds to a 1.0 percent sulfur-content coal. Allowable particulate emissions from industrial processes, expressed in pounds per hour, were a function of tons per hour of input material; the Bay Area Air Pollution Control District Process Weight Rate Standard was employed in this analysis. To control hydrocarbon emissions from industrial process sources, a standard that required a reduction of 90 percent or more by weight was selected. For sulfur dioxide emissions from sources other than fuel combustion, a maximum concentration standard of 500 parts per million by volume was assumed. The control standard for carbon monoxide requires that all emissions be reduced 95 percent by weight. Petroleum storage tanks of more than 40 thousand gallons capacity, with a vapor pressure equal to or greater than 1.5 p.s.i.a. must be equipped with a floating roof, a vapor recovery system, or some other equally efficient device. Gasoline storage tanks with a capacity of 250 gallons or more must be equipped with a submerged filling inlet.

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[2] Except the gray iron foundry industry for which plant by plant control data were available from a post card survey.

[3] These emission standards are discussed in more detail in Appendix A.

E. Selection of Control Alternatives

The final step of the engineering analysis was the identification of applicable air pollution control alternatives. In nearly all cases, the designation of an alternative on which to base the cost estimates was made because of industrial experience with the control alternative. Occasionally, it became apparent that one alternative was clearly superior to all others, but this was the exception rather than the rule. In most cases, there were several alternatives which would meet requirements. For example, the control of particulates can be accomplished by use of cyclones, fabric filters, electrostatic precipitators or wet-type scrubbers and, in the case of combustion equipment, by fuel substitution. Sulfur oxide emissions can be reduced by fuel substitution, gas scrubbing, and sulfur compound recovery systems. In general, the designation of control alternatives for carbon monoxide and hydrocarbons was straightforward since the number of alternatives was more limited. The specific control alternatives on which cost estimates for a given source were based are presented in the related appendix. In general, the size of air pollution control equipment is expressed in terms of gas throughput, and process size - gas volume relationships were determined for each unit process. In addition, certain engineering factors related to equipment cost had to be established, e.g., required pressure drop for venturi scrubbers; construction material; type of fabric filter material; wet- or dry-type electrostatic precipitator, etc. Once these factors were determined, reasonable estimates of purchase, installation, and operating costs could be made. An example of a production - control cost relationship is shown in Figure 2-1 for the control of gray iron cupolas. This figure also illustrates economy of scale.

VI. SOURCE STATISTICS

In order to apply the findings of engineering analysis to control cost estimation, a variety of source statistics were required. These source statistics included regional data for plant location and number of plants, production, capacity, and value of shipments, as applicable.

Primary data on solid waste disposal were obtained from "The National Solid Wastes Survey" and the 1968 National Survey of Community Practices. For stationary combustion sources, the major sources of cost estimating data are given in Table 2-1. The principal sources of these data for industrial process sources are presented in Tables 2-2 through 2-4. Complete citations for most references may be found in the bibliography.

A summary of statistics for industrial process sources is presented in Table 2-5 on page 2-11.

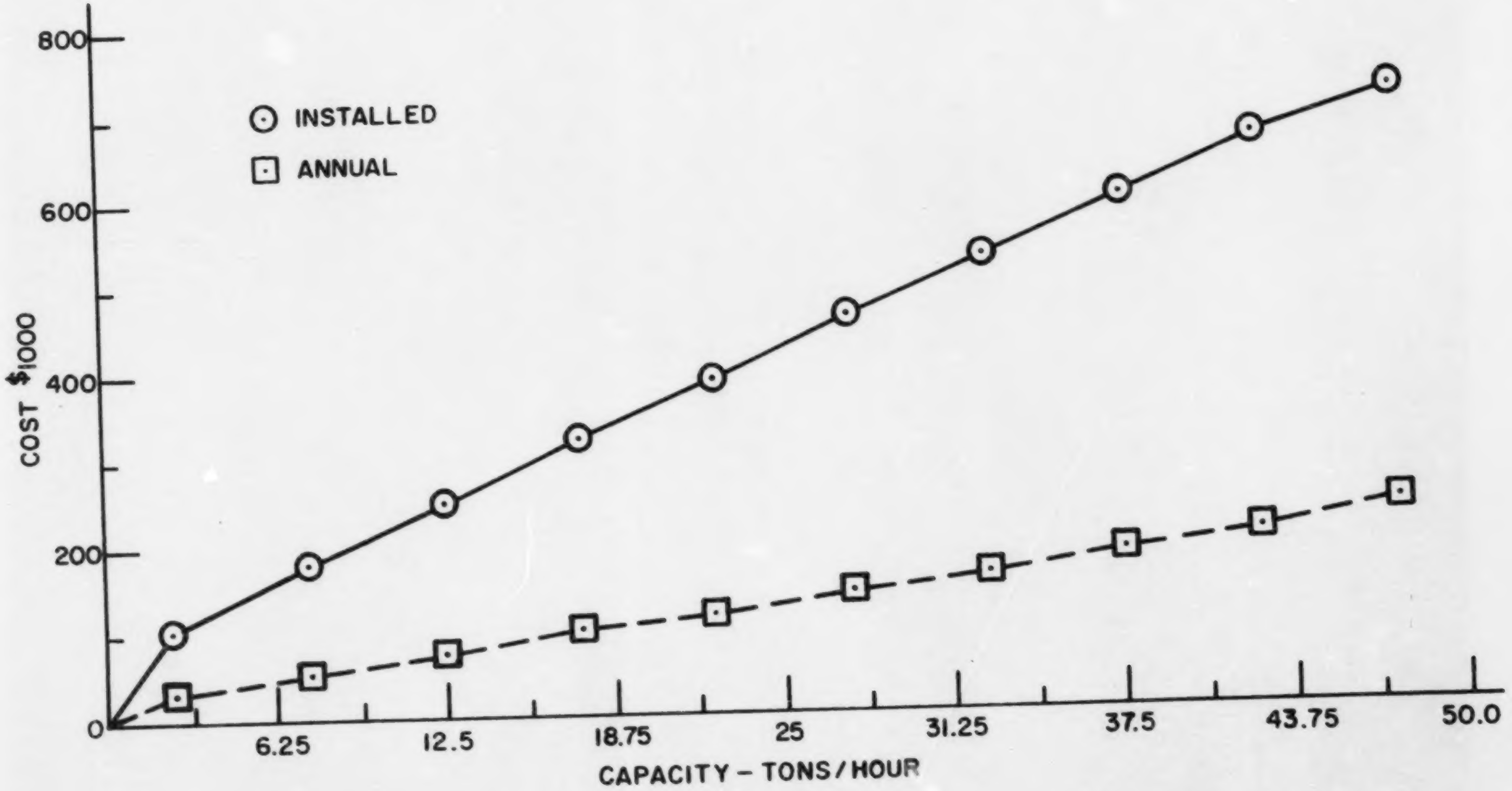

Fig. 2-1. Control Costs versus Gray Iron Cupola Capacity.

Table 2-1

MAJOR SOURCES OF DATA FOR STATIONARY COMBUSTION COST ESTIMATING ANALYSES

Source	Major Document(s)
Steam-electric power generation plants	Steam-Electric Plant Construction Cost and Annual Production Expenses
Industrial boilers	1963 Census of Manufactures
Commercial-institutional heating plants	Supply and Demand for Energy in the U.S. by States and Regions, 1960 and 1967. Interstate Air Pollution Study: St. Louis, Phase II, Project Report, Air Pollution Emissions Inventory
Residential heating plants	1960 Census of Housing

Table 2-2

PRINCIPAL SOURCES OF DATA ON SOURCE LOCATION, NUMBER, AND CAPACITIES

Data Class	
United States	100 Metropolitan Areas
American Bureau of Metal Statistics 1968 Yearbook Directory of Chemical Producers, Stanford Research Institute Directory of American Iron and Steel Works of the United States and Canada, 1967 Rubber Redbook, Directory of the Rubber Industry, 1968 (20th ed.) Waste Trade Directory 1963 Census of Business Rock Products, July 1967 and May 1969 Mimeographed lists, U.S. Bureau of Mines Tape from Dun and Bradstreet List prepared by Resources Research, Inc. N.E.S.S. Report, NAPCA Lists from state highway departments Lists from surveys by U.S. Department of Commerce and NAPCA Telephone contacts with firms	The sources used for the U.S. data on number of employees from 1963 Census of Manufactures and 1964-67 County Business Patterns

Table 2-3

PRINCIPAL SOURCES OF DATA ON PRODUCTION

Data Class	
United States	100 Metropolitan Areas
American Bureau of Metal Statistics 1968 Yearbook Bureau of Mines Minerals Yearbook, 1966 and 1967 Survey of Current Business, 1968 issues 1963 Census of Manufactures 1963 U.S. Census of Business U.S. Industrial Outlook, 1969 "Sulfuric Acid," Current Industrial Reports, 1967 Hot-Mix Asphalt Production and Use Facts for 1967 The Statistics of Paper, 1968 Supplement Feed Situation, ERS, USDA, May 1969	U.S. capacity in the industry was prorated to each of the 100 metropolitan areas on data from the Dun and Bradstreet tape, 1963 Census of Manufactures and 1964-67 County Business Patterns.

Table 2-4

PRINCIPAL SOURCES OF DATA ON SOURCE VALUE OF SHIPMENTS

Data Class	
United States	100 Metropolitan Areas
Census of Manufactures, Preliminary Report 1963 Census of Manufactures 1963 U.S. Census of Business Bureau of Mines Minerals Yearbook, 1967 "Sulfuric Acid," Current Industrial Reports, 1967 U.S. Industrial Outlook 1969 Telephone contacts with firms Estimates of U.S. production Annual Report, International Paper Co., 1966	U.S. value of shipments by industry was prorated to each of the 100 metropolitan areas on the basis of the ratio of metropolitan area to U.S. production.

Table 2-5

1967 STATISTICS FOR INDUSTRIAL PROCESS SOURCES[a]
(nationally and in 100 metropolitan areas)

TYPE OF SOURCE	TOTAL NUMBER OF SOURCES		CAPACITY[b] (million units/year)		PRODUCTION[b] (million units/year)		VALUE OF SHIPMENTS (billions of dollars per year)	
	U.S.	100 Areas	U.S.	100 Areas	U.S.	100 Areas	U.S.	100 Areas
Kraft (sulfate) pulp plants--------------------tons	113	16	32.9	4.1	22.8	2.8	3.4	0.4
Iron and steel plants---------------tons raw steel	141	115	165.0	116.0	127.0	101.0	13.3	10.5
Gray iron foundries[c]------------------tons castings	1,279	661	17.0	10.0	14.3	8.7	2.7	1.7
Primary nonferrous metallurgical plants[d]-------tons	64	12	16.7	3.4	6.4	1.2	3.4	0.6
Sulfuric acid plants----------------------------tons	212	102	38.7	24.4	28.8	18.2	0.3	0.2
Phosphate fertilizer plants--------------tons P_2O_5	171	19	22.9	3.5	8.5	2.3	1.2	0.4
Petroleum refineries-----------------------barrels	262	134	4,210.0	2,530.0	3,580.0	2,380.0	20.3	13.5
Asphalt batching plants[e]--------tons paving mixture	1,500	903	658.0	250.0	216.0	82.0	1.5	0.6
Cement plants------------------------------barrels	176	92	578.0	279.0	378.0	192.0	1.2	0.6
Lime plants-----------------------------------tons	135	67	25.4	9.6	18.0	7.7	0.2	0.1
Coal cleaning plants--------------------------tons	691	109	350.0	61.4	349.0	61.3	1.5	0.3
Petroleum products storage plants[f]----------gallons	29,664	6,130	7.8	5.1	58.6	32.8	17.5	9.8
Grain mills-----------------------------------tons	2,866	907	64.0	43.9	50.5	35.5	4.6	3.7
Grain elevators[g]---------------------------bushels	11,147	1,089	5.5	1.3	18.0	4.4	N.A.	N.A.
Varnish plants-----------------------------gallons	230	216	56.0	52.0	45.4	43.0	0.1	0.1
Rubber plants---------------------tires and tubes	159	102	250.0	170.0	203.0	137.0	3.7	2.5
Secondary nonferrous metallurgical plants-----tons	793	690	2.7	2.4	2.4	2.2	1.6	1.4

[a] The 100 areas are defined in Appendix B; N.A. means not applicable.

[b] The capacity and production are in millions of units (tons, etc.) unless otherwise noted in "Type of Source" column.

[c] Capacity is calculated assuming 1000 operating hours per year.

[d] "Tons" applies to copper, lead, zinc, and aluminum smelters; for copper and lead, capacity is given as input material and production is adjusted to remove effect of a labor strike.

[e] Capacity is calculated assuming 1000 operating hours per year.

[f] Capacity is in billion gallons of gasoline storage space; production, billion gallons of gasoline handled.

[g] Capacity is in billion bushels of storage space; production, billion bushels of throughput.

VII. COST ANALYSES

A. General Approach

Once a control alternative was designated and gas volume and other design specifications determined, control costs were calculated as a function of capacity and other production characteristics. The general array of tasks essential to the estimation of emission control costs is briefly described in this section.[3/] The initial task was that of gathering information about the number of plants or establishments in each of the 100 metropolitan areas. When available, detailed information about the size or capacity of individual processes within each plant was compiled. Most often, employment data were the best available indicator of plant size and, indirectly, exhaust gas volume and emissions. In a few cases, the number of plants or the total capacity in an area had to be estimated because available records were incomplete. The amount of specific information that was obtained determined to a major extent the manner in which cost estimates were calculated.

Another task was to determine which plants needed emission controls, i.e., which plants emitted pollutants in excess of the assumed standards. Information inputs for this task were the 1967 level of control estimates and other factors provided by the engineering analysis described above.

Next, unit cost estimates for control alternatives or a combination of alternatives were computed. Data for these computations were obtained from a variety of sources: surveys, previous NAPCA studies, technical articles on specific control equipment, and articles dealing with specific industries. Unit cost estimates included all recognizable significant elements of costs; both initial investment and continuing annual costs were estimated. In this and all other tasks, the most specific and detailed data obtained were used to insure the best possible results; general information and estimates or assumptions were used only in the absence of specific data.

[3/] Minor but significant variations of the basic technique were necessary; the relevant appendix describes the method for each source category.

To account for the effect of required emission control efficiency on the costs of installed emission control equipment, a set of cost-efficiency parameters called multipliers were derived. The multipliers were derived from the relationship that installed costs for 99-percent control would be double the cost for 90-percent control and that costs for 99.9-percent control would be three times the cost at 90 percent. The three points, i.e., 90 percent equals 1.0, 99.0 equals 2.0, and 99.9 percent equals 3.0 were used to establish an exponential curve from which cost multipliers for other specific control efficiency levels could be read. With the multipliers taken from the curve, costs given in the literature for one level of efficiency can be adjusted for any other efficiency level. As an example, unit cost for a 95-percent efficient control level can be adjusted for 98-percent efficiency as follows:

$$C_{98} = \frac{M_{98}}{M_{95}} \times C_{95}$$

where: C_{98} = cost for 98% control

C_{95} = cost for 95% control

M_{98} = multiplier for 98% control

M_{95} = multiplier for 95% control

Control costs are reported in terms of the initial investment required to implement controls and the continuing annual expenses related to that investment. The investment cost is the total expense of purchasing and installing control equipment. The annual cost is the sum of yearly charges for capital-related costs (interest on the investment funds, property taxes where applicable, insurance premiums, and depreciation charges) plus operating (fuel, labor, utilities, and supplies) and maintenance costs.

For this study, the level of control which existed in an industry as of 1967 was used as a baseline; cost estimates were calculated only for providing controls in excess of the 1967 average level for a pollutant and a source. For example, the 1967 average level of control in the cement industry was 90 percent; therefore, the estimated costs of control reflect expenditures that must be made to comply with the assumed standard by the industry over and above the 1967 baseline of 90 percent. This working assumption follows from the premise that the level of control in effect when the Clean Air Act was amended in 1967 is not attributable to the Act. It was further assumed that the additional sources constructed after 1967 will be controlled at the 1967 control level and hence, only the control required above this level would be attributable to the Act.

B. Accuracy of the Estimates

The estimates for both investment and annualized costs are reported in a manner that indicates their expected accuracy. In addition to the expected cost, which is the estimate calculated from the most specific data and assumptions available, lower and upper limits to the costs are given. The difference between the expected cost and the limits reflects the uncertainty of the data upon which the cost estimates were based.

The lower and upper limits to the estimated expected costs were measured in a systematic manner. This was done by identifying and evaluating the elements of data that were used in calculating the expected costs and then estimating and summing the uncertainty (expressed as a percentage) contributed by each. In each element, there was a degree of uncertainty that varied between elements and between emission sources. The elements of data evaluated for the purpose of estimating total uncertainty were those pertaining to number of emission sources, their locations, their capacities, 1967 levels of control, unit costs for installed control equipment, annual operating and maintenance costs, and values of recovered materials. The study participants who dealt with a particular data element formed, in conference, an estimate of the possible contribution of the data element to the overall uncertainty of the cost estimates. This agreement was reached for each element for each source. The individual uncertainty contributions, expressed as percentages, were summed and the sum was assumed to be a reasonable measure of the total possible uncertainty for each cost estimate. In some cases, it was thought that a data element might be more uncertain in one direction than the other. Accordingly, the positive and negative uncertainty terms were recorded, summed, and applied separately.

C. Amortization Procedures

Except for the gray iron foundry industry and solid waste disposal, estimates of annual control costs were based on ten-year, straight-line (10 percent) depreciation of the indicated investment and 10 percent to cover capital-related charges such as interest, taxes, and insurance. In the gray iron foundry industry, depreciation and capital-related expenses were obtained from plant survey data. For estimates in solid waste disposal, accounting conventions normally used by operators were employed. For all industries, maintenance and other operating expenses were estimated on the basis of the types of process equipment and control equipment involved.

VIII. VALIDITY OF COST ESTIMATES

The validity of control cost estimates for the three major source types, i.e. solid waste, stationary combustion, and industrial process, were found to depend on either the assumptions required, the accuracy of the data available, or both.

The validity of the control costs for solid waste disposal is much less dependent on the accuracy of the data used, but rests almost entirely on the validity of assumptions reflecting anticipated changes in solid waste disposal practices. If these assumptions are accepted, quite reliable control cost estimates can be made from the data base available.

Estimating control costs for the four stationary combustion sources also required the adoption of a major assumption reflecting a widespread changeover to low-sulfur fuel oil. In addition, with the exception of steam-electric power plants, data base insufficiencies also existed. Therefore, the validity of these cost estimates varies with the apparent sensitivity of the estimate to the various data inadequacies. The four stationary combustion sources should be ranked in terms of validity as follows:

a) Steam-electric power plants.

b) Industrial boilers.

c) Commercial-institutional heating plants and residential heating plants.

In estimating control costs for industrial process sources, a variety of methods were used; the method used depended largely upon the degree of accuracy of the data available. The result is that the validity of the cost estimates varies. In this regard, the industries dealt with can be divided into three classifications:

a) Those for which detailed data on emissions and costs are available from NAPCA studies.

   These data permitted accurate estimates of costs that may be incurred in the following industries: pulp, iron and steel, gray iron foundry, and primary nonferrous metallurgical (primary copper, lead, and zinc).

b) Those for which special studies have not been made but data are available on technical process variables.

   These data made it possible to estimate emissions and control costs by applying factors developed by NAPCA and others. This group includes the following industries: sulfuric acid, phosphate fertilizer, petroleum refining, asphalt batching, cement, lime, coal cleaning, and petroleum products storage.

c) Those for which little or no detailed data about the specific industry are available.

   In these industries, emission and cost estimates were based on relevant process parameters and knowledge of other types of industrial processes; the estimates are, at best, rough approximations of the expenditures that may be required to control emissions. This group includes the following industries: grain milling and handling, varnish, rubber (tires and inner tubes), and primary nonferrous metallurgical (primary aluminum reduction) and secondary nonferrous metallurgical (aluminum, copper, lead, and zinc recovery).

Chapter 3

Cost Estimates

I. INTRODUCTION

As stated in Chapter 1, the purpose of this research was to make estimates of the air pollution control costs that may be expected from the implementation of the Clean Air Act, as Amended. This chapter presents estimates of the investment and annual costs of controlling particulate, sulfur oxide, hydrocarbon, and carbon monoxide emissions in 100 metropolitan areas of the United States. Total implementation costs, costs by source, and costs by metropolitan area are presented in the following sections. Metropolitan area costs and source costs by fiscal year are presented in Appendixes D and E through Y, respectively.

II. TOTAL IMPLEMENTATION COSTS

Implementation of the Act in the 100 metropolitan areas would require an estimated investment of $2.64 billion with annual costs reaching $1.88 billion by FY 1975. The total investment cost includes $221 million, $1.29 billion, and $1.13 billion to control emissions from solid waste disposal, stationary combustion, and industrial process sources, respectively. The corresponding annual costs, as well as annual and investment costs by fiscal year, are shown in Table 3-1.

III. SOURCE COSTS

In Table 3-2, investment and annual costs to control emissions in the 100 metropolitan areas are shown by source. It can be seen that the control of emissions from stationary combustion sources is the most costly of the three major source categories. The largest investment cost among

Table 3-1

PROJECTED COSTS FOR CONTROLLING FACILITIES IN 100 METROPOLITAN AREAS[a]
(million dollars)

FISCAL YEAR	COSTS BY SOURCE CATEGORY FOR FACILITIES OPERATING IN CALENDAR YEAR 1967								COSTS BY SOURCE CATEGORY FOR FACILITIES EXPECTED TO BE OPERATING AT END OF FY75[b]							
	Solid Waste Disposal		Stationary Combustion		Industrial Processes		Total Area Control Cost		Solid Waste Disposal		Stationary Combustion		Industrial Processes		Total Area Control Cost	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
FY71	10	5	65	70	41	21	116	96	17	8	82	107	78	37	177	152
FY72	45	27	268	359	208	108	521	494	56	35	291	445	261	147	608	627
FY73	67	60	416	765	344	237	827	1062	80	74	443	912	410	303	933	1290
FY74	39	79	306	1000	224	317	569	1396	50	98	331	1200	278	404	659	1710
FY75	10	84	123	1090	65	340	198	1514	18	107	142	1330	104	443	264	1880
Totals	171	255	1178	3284	882	1023	2231	4562	221	322	1289	3994	1131	1334	2641	5659

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[a] Projected costs (Inv., Ann.) are the initial investment expenditure (for purchasing and installing control equipment) and the sum of continuing annual costs (for interest, property taxes, insurance, depreciation, etc., and for operating and maintaining equipment). The 100 areas are defined in Appendix B.

[b] These costs include control expenditures for 21 sources with facilities operating in calendar year 1967 plus additional facilities expected to be operating by the end of FY75.

Table 3-2

TOTAL CONTROL COST BY THE END OF FISCAL YEAR 1975
(100 metropolitan areas)

TYPE OF SOURCE	TOTAL CONTROL COST (million dollars)[a]	
	Investment	Annual
SOLID WASTE DISPOSAL	219.0	323.0
STATIONARY COMBUSTION		
Steam-electric power plants	161.0	2430.0
Industrial boilers	546.0	1180.0
Commercial-institutional heating plants	30.7	16.6
Residential heating plants	550.0	376.0
Totals	1287.7	4002.6
INDUSTRIAL PROCESS		
Kraft (sulfate) pulp plants	7.8	6.5
Iron and steel plants	413.0	824.0
Gray iron foundries	238.0	195.0
Primary nonferrous metallurgical plants	86.5	82.6
Sulfuric acid plants	37.3	7.2
Phosphate fertilizer plants	5.3	5.5
Petroleum refineries	104.0	4.7
Asphalt batching plants	36.8	78.7
Cement plants	19.4	16.4
Lime plants	0.7	1.5
Coal cleaning plants	2.6	2.7
Petroleum products storage plants	84.0	0.0
Grain mills and elevators	46.1	45.0
Varnish plants	0.9	3.0
Rubber (tire and inner tube) plants	4.9	12.5
Secondary nonferrous metallurgical plants	49.9	52.2
Totals	1137.2	1327.5

[a] Projected costs (Inv., Ann.) are the initial investment expenditure (for purchasing and installing control equipment) and the sum of continuing annual costs (for interest, property taxes, insurance, depreciation, etc., and for operating and maintaining equipment). The 100 areas are defined in Appendix B.

the stationary combustion sources will be required to control emissions from residential heating plants ($550 million). Investment costs to control industrial process emissions range from $700 thousand for lime plants to $413 million for iron and steel plants. Annual costs range from zero for petroleum products storage plants to $824 million for iron and steel plants.

The relationship between annual control cost and capacity and value of shipments for the industrial process sources studied is shown in Table 3-3. The annual control cost shown is for FY 1975 and, as such, is a continuing cost of air pollution control. The relative cost estimates in Table 3-3 permit a cursory examination of the economic impact of air pollution control on industrial process sources.

IV. METROPOLITAN AREA COSTS

In this section, cost estimates, by major source category, are presented for each of the 100 metropolitan areas. The estimates vary considerably from one area to another. While of interest, no attempt was made to analyze inter-area cost variation; the time available for the research precluded such a detailed study. However, certain relevant factors are obvious and are mentioned below.

A. Total Implementation

In Table 3-4, which may be found at the end of this chapter, the total investment costs (FY 1971-1975) and the FY 1975 annual costs to control 1967 base year emissions from solid waste disposal, stationary combustion, and industrial process sources are given for each metropolitan area. The FY 1975 annual cost estimate is included in Table 3-4 since it is a continuing cost of air pollution control.[1/]

As would be expected, the metropolitan areas for which cost estimates are the highest include the very large, highly industrialized, more northern cities of Chicago, New York, Pittsburgh, Philadelphia, Cleveland, Detroit,

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[1/] Estimated investment and annual costs by fiscal year for each metropolitan area are given in Appendix D.

Table 3-3

EXPECTED ANNUAL CONTROL COSTS RELATIVE TO CAPACITY AND SHIPMENTS OF INDUSTRIAL PROCESS SOURCES[a]
(1967 base; 100 metropolitan areas)

TYPE OF SOURCE	SOURCE TOTALS			RELATIVE COST	
	Capacity (millions of units)	Value of Shipments (billion dollars)	Annual Control Cost (million dollars)	Cost per Unit of Annual Capacity (dollars per unit)	Cost per 100 Dollars of Shipment (dollars)
Kraft (sulfate) pulp plants------------------tons	4.1	0.4	2.5	0.61	0.63
Iron and steel plants--------------tons raw steel	116.0	10.5	204.0	1.76	1.94
Gray iron foundries-----------------tons castings[b]	10.0	1.7	49.1	4.91	2.89
Primary nonferrous metallurgical plants------tons[c]	3.4	0.6	23.5	6.91	3.92
Sulfuric acid plants--------------------------tons	24.4	0.2	2.2	0.09	1.10
Phosphate fertilizer plants-------------tons P_2O_5	3.5	0.4	5.5	1.57	1.39
Petroleum refineries----------------------barrels	2530.0	13.5	1.4	0.00	0.01
Asphalt batching plants-------tons paving mixture[d]	250.0	0.6	18.6	0.74	3.10
Cement plants----------------------------barrels	279.0	0.6	5.7	0.02	0.95
Lime plants---------------------------------tons	9.6	0.1	0.5	0.05	0.50
Coal cleaning plants-------------------------tons	61.4	0.3	0.5	0.01	0.17
Petroleum products storage plants---------gallons[e]	5140.0	9.8	0.0	0.00	0.00
Grain mills----------------------------------tons	43.9	3.7	7.9	0.18	0.21
Grain elevators--------------------------bushels[f]	1330.0	N.A.	7.5	0.01	N.A.
Varnish plants---------------------------gallons	52.0	0.1	0.8	0.02	0.80
Rubber plants--------------------tires and tubes	170.0	2.5	2.5	0.01	0.10
Secondary nonferrous metallurgical plants----tons	2.4	1.4	11.9	4.96	0.85

[a] Costs for controlling particulate, sulfur oxide, hydrocarbon, and carbon monoxide emissions from facilities operating in calendar year 1967. The areas are defined in Appendix B. N.A. means not applicable.

[b] Capacity is calculated assuming 1000 operating hours per year.

[c] Tons applies to copper, lead, zinc, and aluminum smelters; for copper and lead, capacity is input material.

[d] Capacity is calculated assuming 1000 operating hours per year.

[e] Capacity is in million gallons of gasoline storage space.

[f] Capacity is in million bushels of storage space.

and St. Louis. The lowest cost estimates are for such areas as Jackson (Miss.), Burlington (Vt.), Cheyenne, Albuquerque, and San Diego. The Virgin Islands have negligible investment and annual costs.

Figure 3-1 illustrates the distribution of total investment costs over the 100 metropolitan areas; as shown, costs in 73 of the areas are less than $20 million. The distribution of total FY 1975 annual costs is shown in Figure 3-2; costs in 81 of the areas are less than $20 million. Not surprisingly, investment and annual costs in several areas exceed $70 million.

B. Solid Waste Disposal

FY 1971-1975 investment and FY 1975 annual costs to control pollutant emissions from solid waste disposal are also presented for each area in Table 3-4. Control costs for solid waste disposal are primarily a function of population and the method of disposal, whether landfill, open burning, or incineration. The highest cost estimates are for large communities now using open burning; the control alternative costed is either incineration, with gas cleaning, or sanitary landfill.

In Figure 3-1 it can be seen that the estimated FY 1971-1975 investment costs in 98 of the areas are less than $10 million; FY 1975 annual costs are less than $10 million in 99 areas (Figure 3-2). Only New York, at $10.6 million, exceeds $10 million.

C. Stationary Combustion

Table 3-4 also shows the estimated FY 1971-1975 investment costs and FY 1975 annual costs to control particulate and sulfur oxide emissions from stationary combustion sources.

For many of the metropolitan areas studied, control of stationary combustion sources resulted in the greatest estimated cost. The bulk of this cost was for control of particulate and sulfur oxide emissions from coal combustion. However, the use of high-sulfur content oil also resulted in significant sulfur oxide emissions. Control of stationary combustion emissions by fuel switching was assumed for cost estimation; control

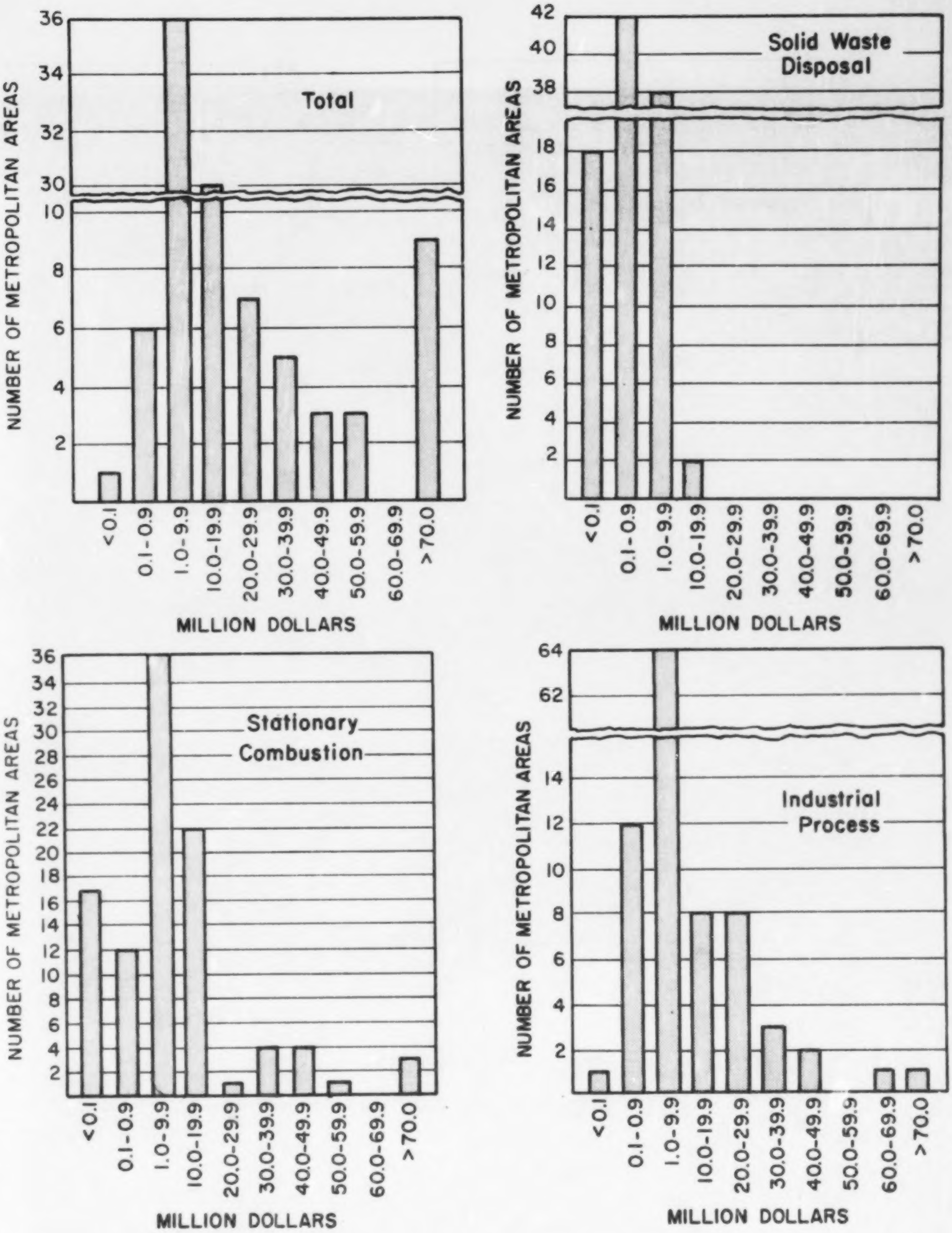

Fig. 3-1. Distribution of FY 1971-1975 Investment Costs.

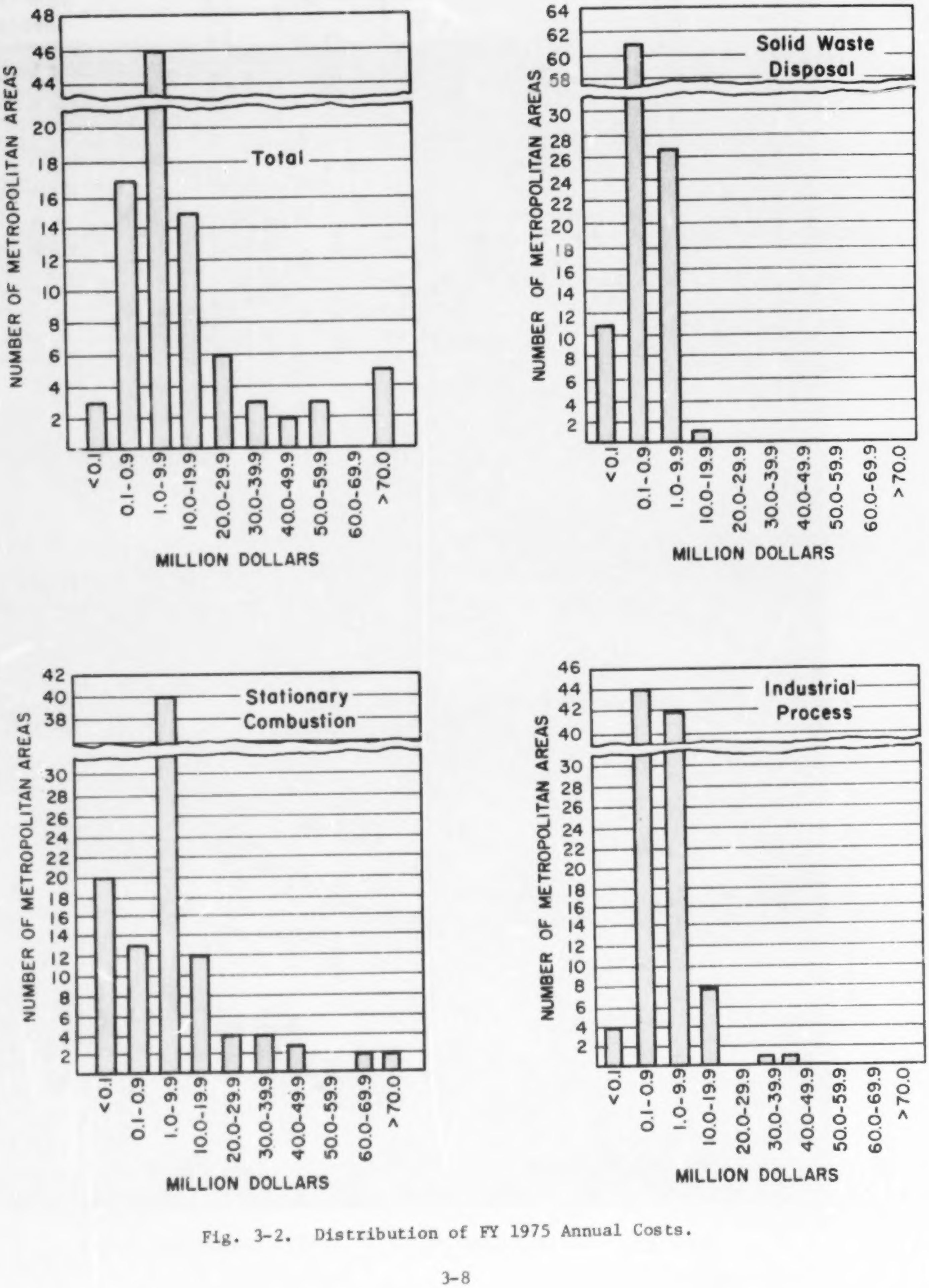

Fig. 3-2. Distribution of FY 1975 Annual Costs.

costs tended to be proportional to the amount of coal burned. As a result, 20 of the areas where negligible amounts of coal were burned showed negligible to zero costs. These cost estimates were based on projections from the base year 1967 and knowledge that the use of coal for heating residential and commercial and institutional structures has been declining steadily throughout the country. In fact, its use had become insignificant in some areas by 1967. This will be true for most metropolitan areas by 1975. In some areas, switching from coal to oil, gas, or electricity resulted in a significant saving in fuel costs which has accelerated the trend toward the use of cleaner fuels. The price differential resulting from fuel cost savings explains the negative annualized control cost in six areas.

As shown in Figure 3-1, FY 1971-1975 investment costs are less than $20 million in 87 of the 100 areas. Annual costs for FY 1975 (Figure 3-2) are less than $20 million in 85 areas.

D. Industrial Process

The estimated FY 1971-1975 investment costs and FY 1975 annual costs to control industrial process emissions in each metropolitan areas are shown in Table 3-4. Twenty of the metropolitan areas studied are in the industrial northeastern states of Massachusetts, Connecticut, New York, New Jersey, and Pennsylvania with another 18 in Ohio, Indiana, Michigan, and Illinois, also highly industrialized states. The estimated costs of control for these areas indicate the range of air pollution control costs for industrial SMSA's.

The estimated FY 1971-1975 investment costs are less than $10 million in 77 metropolitan areas (Figure 3-1). In 90 areas the estimated FY 1975 annual costs are less than $10 million (Figure 3-2).

Table 3-4

1967 BASE YEAR
AIR QUALITY CONTROL COSTS
TOTAL INVESTMENT (FY 1971-1975) and FY 1975 ANNUAL COSTS BY METROPOLITAN AREA[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
GROUP I:												
1. Washington	1.3	0.4	43.0	25.8	3.3	2.1	35.6	21.9	47.6	28.3	63.2	35.6
2. New York	24.4	6.3	88.6	79.8	17.0	10.6	85.1	71.6	130.0	96.7	148.2	116.0
3. Chicago	93.7	48.9	119.0	173.2	15.1	6.9	157.3	167.2	227.8	229.0	314.4	300.0
4. Philadelphia	47.0	14.6	43.2	40.8	3.3	1.6	74.7	41.6	93.5	57.0	154.3	74.1
5. Denver	4.2	1.4	4.8	15.6	6.0	2.1	10.4	14.9	15.0	19.1	20.2	23.7
6. Los Angeles	19.1	8.2	--	3.8	--	--	12.5	8.3	19.1	12.0	25.5	16.0
7. St. Louis	21.6	6.9	50.7	65.7	3.7	1.3	53.5	54.2	76.0	73.9	107.2	96.8
8. Boston	6.1	1.4	18.1	6.3	7.2	3.4	22.6	8.3	31.4	11.1	42.0	12.5
9. San Francisco	8.6	3.2	--	1.9	--	--	5.6	3.3	8.6	5.1	11.8	7.0
10. Pittsburgh	60.8	37.4	39.4	41.7	7.4	3.2	76.2	59.3	107.6	82.3	142.1	107.0
11. Buffalo	25.4	13.5	45.9	21.9	3.3	1.6	52.9	25.9	74.6	37.0	100.7	51.1
12. Cincinnati	21.8	5.4	31.4	39.3	3.9	1.9	43.9	37.4	57.1	46.6	77.0	62.9
13. Cleveland	40.2	17.9	39.8	38.0	9.2	4.0	62.0	42.6	89.2	59.9	120.4	80.9
GROUP II:												
14. Kansas City	10.1	2.7	3.0	6.6	0.4	0.5	8.6	7.3	13.5	9.8	19.3	12.1
15. Baltimore	22.4	10.8	15.1	15.0	5.3	2.3	30.8	20.9	42.8	28.1	55.6	35.4
16. Minneapolis-St. Paul	13.4	4.7	14.9	12.5	5.2	2.1	23.1	14.5	33.5	19.3	46.6	24.1
17. Hartford[b]	6.2	2.1	6.8	9.7	6.3	2.8	13.4	11.0	19.3	14.6	26.1	18.3
18. Indianapolis	5.2	1.3	16.7	12.7	3.1	1.3	17.5	11.1	25.0	15.3	34.5	20.5
19. Detroit	32.8	14.0	39.6	69.6	9.4	4.3	57.8	63.4	81.8	87.9	110.5	117.8
20. Milwaukee Kenosha/Racine	8.8	2.4	43.5	32.3	4.1	1.8	35.7	27.4	56.4	36.5	68.8	47.1
21. Providence-Pawtuckett/Fall River	6.3	1.7	--	2.8	2.5	1.1	6.0	5.1	8.8	5.6	11.7	7.0
22. Seattle-Everett/Tacoma	14.2	5.3	2.5	-0.1	0.6	0.6	9.0	3.3	17.2	5.8	20.1	7.3
23. Louisville	4.6	1.4	19.1	39.2	1.8	0.9	17.9	31.1	25.5	41.5	35.0	53.9
24. Dayton	4.4	1.3	11.6	11.8	2.4	1.0	12.8	10.4	18.4	14.1	25.3	18.2
25. Phoenix	2.0	0.7	18.7	0.3	0.3	0.3	13.2	0.9	21.0	1.3	30.9	2.0

See footnotes at end of table.

Table 3-4 (continued)

1967 BASE YEAR
AIR QUALITY CONTROL COSTS
TOTAL INVESTMENT (FY 1971-1975) and FY 1975 ANNUAL COSTS BY METROPOLITAN AREA[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
26. Houston/ Galveston- Texas City	33.8	7.4	12.4	3.1	5.1	2.3	34.3	9.1	51.3	12.8	75.7	16.7
27. Dallas/Ft. Worth	7.7	2.1	9.3	2.3	0.7	0.8	13.2	3.8	17.7	5.2	22.8	6.7
28. San Antonio	2.1	0.6	3.3	0.8	0.3	0.3	4.0	1.3	5.7	1.7	7.2	2.2
29. Birmingham	20.3	10.2	5.3	21.3	0.2	0.2	18.3	24.1	25.8	31.7	33.6	39.5
30. Toledo	6.7	1.0	5.9	13.9	0.2	0.3	8.4	12.0	12.8	15.2	18.8	18.4
31. Steubenville/ Weirton/ Wheeling	21.1	12.3	24.7	43.1	0.1	0.1	33.5	42.0	45.9	55.5	60.8	70.2
32. Chattanooga	3.8	1.1	1.1	0.5	0.1	0.1	3.3	1.1	5.0	1.7	6.8	2.4
33. Atlanta	4.3	1.3	3.1	9.0	3.3	1.5	7.6	9.1	10.7	11.8	13.9	14.3
34. Memphis	3.2	0.9	0.9	-0.3	0.2	0.3	3.0	0.5	4.3	0.9	6.1	1.2
35. Portland	19.0	6.6	0.3	--	2.8	1.1	12.4	4.3	22.0	7.7	27.2	9.5
GROUP III:												
36. Salt Lake City	6.7	3.3	10.0	2.9	1.9	0.6	11.7	4.1	18.6	6.8	26.6	9.0
37. New Orleans	33.1	7.7	--	--	1.6	1.3	17.9	4.9	34.7	9.0	43.0	11.0
38. Miami/Fort Lauderdale	3.6	0.5	0.4	0.3	3.1	1.8	3.6	1.9	7.1	2.6	9.3	3.3
39. Oklahoma City	1.6	0.5	12.9	2.2	0.2	0.2	9.6	1.9	14.7	2.9	21.9	4.3
40. Omaha	2.8	0.8	12.8	5.5	0.2	0.2	10.8	4.8	15.8	6.5	22.4	8.4
41. Honolulu	1.4	0.3	--	1.7	2.2	0.8	2.4	2.2	3.6	2.8	4.6	3.5
42. Beaumont-Port Arthur-Orange	15.0	0.7	0.0	0.0	0.1	0.1	8.1	0.5	15.1	0.9	28.0	1.1
43. Charlotte	2.1	0.5	9.9	3.0	0.1	0.1	7.9	2.4	12.1	3.6	17.7	5.4
44. Portland,Maine	1.6	0.3	3.1	0.7	--	0.1	4.0	0.7	4.7	1.1	8.0	1.6
45. Albuquerque	0.7	0.2	0.1	--	0.1	0.1	0.7	0.2	0.9	0.3	1.1	0.4
46. Lawrence- Haverhill/ Lowell/ Manchester	1.1	0.3	1.4	2.3	1.3	0.5	2.6	2.5	3.8	3.1	5.0	4.0
47. El Paso	5.0	1.9	--	--	0.1	0.1	2.6	1.1	5.1	2.0	7.6	2.5

Table 3-4 (continued)

1967 BASE YEAR
AIR QUALITY CONTROL COSTS
TOTAL INVESTMENT (FY 1971-1975) and FY 1975 ANNUAL COSTS BY METROPOLITAN AREA[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
48. Las Vegas	1.0	0.3	0.1	--	1.1	0.4	1.5	0.4	2.2	0.6	3.0	0.8
49. Fargo-Moorhead	1.7	0.5	1.9	-0.5	--	--	2.6	--	3.6	--	5.1	0.1
50. Boise	0.6	0.1	1.6	0.1	--	--	1.6	0.1	2.2	0.3	2.9	0.3
51. Billings	2.8	0.2	--	--	--	0.1	1.5	0.2	2.8	0.3	5.4	0.4
52. Sioux Falls	0.6	0.1	0.2	0.2	--	0.1	0.6	0.3	0.8	0.4	1.0	0.5
53. Cheyenne	0.7	0.1	0.3	--	--	--	0.6	0.1	1.0	0.1	1.6	0.3
54. Anchorage	0.2	--	--	-0.1	--	0.1	0.1	--	0.2	--	0.4	--
55. Burlington	0.1	--	1.2	0.2	--	--	0.8	0.2	1.3	0.3	1.8	0.4
56. San Juan	0.2	--	--	0.7	0.2	0.2	0.3	0.8	0.4	1.0	0.4	1.2
57. Virgin Islands	--	--	--	--	--	--	--	--	--	--	--	--
GROUP IV:												
58. Allentown-Bethlehem-Easton	12.5	6.8	18.9	14.0	2.0	0.6	24.1	15.0	33.4	21.4	45.3	29.1
59. Anderson/Muncie	1.3	0.4	6.8	4.3	--	0.1	5.7	3.2	8.1	4.8	11.7	7.0
60. Bakersfield	2.7	0.7	--	--	--	--	1.8	0.4	2.7	0.7	3.6	1.2
61. Columbus	4.3	1.2	4.5	1.2	0.3	0.3	6.3	1.8	9.1	2.7	12.7	3.8
62. Davenport-Rock Island-Moline	5.5	1.6	10.3	1.3	0.1	0.1	10.8	2.0	15.9	3.0	22.4	4.2
63. Flint	2.3	0.7	0.5	3.4	0.2	0.2	2.0	2.8	3.0	4.3	4.1	6.3
64. Grand Rapids/Muskegon-Muskegon Hts.	3.9	1.1	6.0	19.1	0.2	0.3	7.2	16.0	10.1	20.5	13.5	24.9
65. Greensboro	2.5	0.5	0.9	0.7	0.1	0.1	2.4	0.9	3.5	1.3	4.8	1.9
66. Harrisburg	6.4	3.9	16.8	4.0	1.6	0.5	17.2	6.0	24.8	8.4	33.4	12.9
67. Jacksonville	3.4	0.7	0.1	2.0	2.2	1.0	4.2	2.9	5.7	3.7	7.4	4.6
68. Knoxville	11.4	4.0	7.9	2.6	0.2	0.2	11.3	3.9	19.4	6.8	25.7	9.0
69. Nashville	2.0	0.4	0.7	-0.3	0.2	0.2	2.0	0.2	2.9	0.3	3.8	0.4

Table 3-4 (continued)

1967 BASE YEAR
AIR QUALITY CONTROL COSTS
TOTAL INVESTMENT (FY 1971-1975) and FY 1975 ANNUAL COSTS BY METROPOLITAN AREA[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
70. Peoria	5.1	1.6	11.7	10.8	0.1	0.1	12.0	9.3	16.9	12.5	23.2	16.3
71. Richmond	2.4	0.7	10.1	2.7	0.2	0.2	9.3	2.5	12.7	3.6	17.3	4.8
72. Rochester	2.3	0.6	5.6	6.6	3.2	1.4	7.7	6.0	11.1	8.6	15.2	11.9
73. Saginaw/Bay City	4.4	1.1	11.6	20.0	0.1	0.1	11.1	16.2	16.1	21.2	22.0	27.2
74. Scranton/Wilkes Barre-Hazelton	0.6	0.1	79.6	15.1	0.2	0.2	58.8	11.2	80.4	15.4	110.4	21.2
75. Syracuse	3.3	1.1	3.6	0.9	0.2	0.2	5.0	1.5	7.1	2.2	9.8	3.1
76. Tampa	8.1	2.2	0.2	10.6	1.9	1.0	7.2	10.6	10.2	13.8	13.2	16.9
77. Tulsa	5.3	1.6	13.2	2.6	0.3	0.2	10.8	2.6	18.7	4.4	23.9	7.1
78. Worcester/Fitchburg-Leominster	1.1	0.4	1.4	0.3	0.3	0.2	2.9	0.6	4.1	0.9	5.6	1.2
79. Youngstown-Warren	23.7	17.4	8.4	5.0	1.7	0.6	24.1	15.1	33.8	23.0	44.5	29.6
GROUP V:												
80. Albany-Schenectady-Troy	3.4	0.9	3.2	5.2	2.0	0.8	5.7	5.0	8.6	6.9	11.2	10.0
81. Binghamton	1.8	0.7	7.7	3.0	1.0	0.4	6.6	2.6	10.5	4.1	14.7	6.2
82. Charleston, South Carolina	3.9	1.1	2.6	1.6	0.1	0.1	4.3	1.9	6.6	2.8	8.5	3.8
83. Charleston, West Virginia	1.0	0.2	5.8	15.7	0.6	0.2	5.3	11.8	7.4	16.1	10.2	21.7
84. Des Moines	1.7	0.5	9.0	3.6	0.1	0.1	7.4	2.7	10.8	4.2	15.3	5.2
85. Fresno	1.6	0.7	--	--	--	--	1.1	0.3	1.6	0.7	2.4	1.0
86. Fort Wayne	1.6	0.5	5.4	4.2	0.1	0.1	4.5	3.2	7.1	4.8	10.2	7.0
87. Jackson, Mississippi	1.4	0.3	--	--	0.1	0.1	1.0	0.3	1.5	0.4	2.0	0.5
88. Johnstown	6.9	4.5	17.6	1.2	--	0.1	17.6	3.9	24.5	5.8	33.5	7.9
89. Lancaster	3.4	1.1	6.8	2.9	0.1	0.1	5.5	3.1	10.3	4.1	14.0	7.2
90. Mobile	3.2	0.8	7.5	8.2	0.1	0.2	6.0	7.2	10.8	9.2	12.5	11.4
91. Norfolk-Portsmouth/Newport News-Hampton	4.2	0.8	12.5	5.1	2.4	1.1	13.3	4.7	19.1	7.0	27.0	10.5
92. Raleigh/Durham	0.6	0.2	5.6	1.4	0.1	0.1	4.2	1.1	6.3	1.7	9.4	2.5
93. Reading	4.0	1.3	12.8	4.3	0.1	0.1	14.8	4.4	16.9	5.7	22.8	7.5
94. Rockford	0.9	0.4	8.8	4.8	--	0.1	6.3	3.7	9.7	5.3	14.6	7.6
95. Sacramento	0.8	0.4	--	--	--	--	0.6	0.2	0.8	0.4	1.2	0.5
96. San Diego	0.8	0.4	--	--	--	--	0.6	0.2	0.8	0.4	1.3	0.5
97. South Bend	3.8	1.2	11.4	9.5	0.1	0.1	10.5	7.7	15.3	10.8	22.0	14.7
98. Utica-Rome	1.1	0.5	3.2	0.4	1.4	0.4	4.1	0.9	5.7	1.3	7.6	1.8
99. Wichita	4.6	0.7	--	--	0.1	0.1	2.9	0.6	4.7	0.8	7.8	1.2
100. York	2.4	0.8	4.3	7.1	1.6	0.5	5.9	6.4	8.3	8.4	11.1	12.1

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[a] The 100 areas are listed by groups in Appendix B; blanks (--) indicate negligible expenditure required. "Inv." is investment and "Ann." is annual cost.

[b] Also includes New Haven/Waterbury/Meridan SMSA's, although not in originally proposed AQCR.

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Chapter 4

Emission Reductions

I. INTRODUCTION

This chapter presents estimates of particulate, sulfur oxide, hydrocarbon, and carbon monoxide emissions from solid waste disposal, stationary combustion, and industrial process sources for 1967 and 1975, with and without implementation of the Clean Air Act. Emission reductions are discussed on a metropolitan area and individual source basis. For comparative purposes, the investment and ultimate annual costs of reducing emissions are also included.

II. METROPOLITAN AREA SUMMARY

A. Introduction

The cost estimates given in Chapter 3 are more meaningful when related to the associated reductions in pollutant emissions. In this study, estimates were made of the emissions and the percentage of control in effect, by source, within 100 metropolitan areas as of 1967 and for fiscal years 1971 through 1975. These estimates were aggregated for the 100 areas, by source and type of pollutant, and include 18 sources of particulate emissions, 7 of sulfur oxide emissions, 4 of hydrocarbon emissions, and 3 of carbon monoxide emissions. For 1967, it is estimated that the selected sources in the 100 metropolitan areas accounted for 53 percent of the total particulate emissions, 48 percent of sulfur oxide emissions, 48 percent of hydrocarbon emissions, and 33 percent of carbon monoxide emissions from like sources in the entire United States.

Table 4-1 presents a summary of the estimates of 1967 and 1975 emissions and control levels for sources in the 100 metropolitan areas, illustrating the potential effectiveness of the proposed implementation plan.

Table 4-1

EMISSIONS AND CONTROL LEVELS FOR 100 METROPOLITAN AREAS WITH AND WITHOUT IMPLEMENTATION OF THE ACT, 1967 and 1975

Pollutant	Source Category	1967 Emissions (1000 tons)	1967 Control Level (percent)	1975 Emissions at 1967 Control Level (1000)	1975 Emissions at 1975 Control Level (1000)	1975 Control Level (percent)	Emission Decrease (percent)
Particulates	Solid Waste	844	53.5	947	187	89.4	77.8
	Stationary Combustion	3960	78.1	4722	391	98.2	91.7
	Industrial Process	3634	67.6	4656	505	96.6	86.1
Sulfur Oxides	Solid Waste	--	--	--	--	--	--
	Stationary Combustion	12548	0.0	15136	6001	61.2	52.2
	Industrial Process	1547	30.5	1866	987	65.8	36.2
Hydrocarbons	Solid Waste	160	63.0	204	49	91.1	69.4
	Stationary Combustion	--	--	--	--	--	--
	Industrial Process	1228	51.2	1498	518	83.2	57.8
Carbon Monoxide	Solid Waste	1950	63.0	2089	299	94.5	84.7
	Stationary Combustion	--	--	--	--	--	--
	Industrial Process	2330	34.6	3043	228	95.0	90.2

-- Emission levels meet applicable regualtions.

For convenience and to emphasize the potential impact of the plan, pollutant sources have been grouped into the three categories: solid waste disposal, stationary combustion, and industrial process. In so doing, some detail has been lost.

B. Particulates

Particulate emissions from solid waste disposal sources were 840 thousand tons in 1967. Emissions from stationary combustion sources amounted to 3960 thousand tons in 1967 (Table 4-2), nine-tenths of which were from steam-electric power plants and industrial boilers. The balance of stationary combustion emissions was from commercial-institutional and residential heating plants. Steam-electric plants and industrial boilers are distributed rather unevenly throughout the metropolitan areas and not uniformly with population. In contrast, residential and commercial-institutional heating plants are distributed more uniformly with population. Emissions from residential and commercial-institutional sources will be less effectively controlled than steam-electric and industrial emissions by 1975.

Among the industrial process sources, iron and steel plants, grain mills, and cement plants were the largest sources of particulates in 1967, accounting for approximately 61 percent of the total (Table 4-3). With iron and steel industry emission control levels increased to 95.5 percent in 1975 and grain elevator and cement plant levels increased to 99 percent, this disproportion will be substantially reduced. Iron and steel plants will, however, remain the largest contributor of particulate emissions in 1975.

C. Sulfur Oxide

The largest source of sulfur oxide emissions among stationary combustion sources was steam-electric generating stations (Table 4-2). They accounted for more than 64 percent of the estimated emissions for this group in 1967 when there was little significant control of emissions.

Table 4-2

ESTIMATED 1967 EMISSION LEVELS - STATIONARY COMBUSTION SOURCES[a]

TYPE OF SOURCE	TOTAL NUMBER OF SOURCES		TOTAL QUANTITY OF EMISSIONS[b] (1000 tons/year)							
			United States				100 Metropolitan Areas			
	U.S.	100 Areas	Part	SO_x	HC	CO	Part	SO_x	HC	CO
Steam-electric power plants[c]	410	252	5550	15000	--	--	2190	6860	--	--
Industrial boilers (thousands)	307	219	3000	5260	--	--	1540	3970	--	--
Commercial-institutional heating plants (thousands)	999	607	105	1110	--	--	64	675	--	--
Residential heating plants (millions)	58	35	314	1530	--	--	163	1040	--	--
Totals- -			8970	22900	--	--	3960	12500	--	--

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[a] Totals for facilities in operation in 1967. Blanks in the table indicate the emission levels meet applicable regulations (App. A).

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO).

[c] Plants of 25 megawatts and greater using coal and/or oil.

Table 4-3

ESTIMATED 1967 EMISSION LEVELS - INDUSTRIAL PROCESS SOURCES

TYPE OF SOURCE	TOTAL NUMBER OF SOURCES		TOTAL QUANTITY OF EMISSIONS[b] (1000 tons/year)							
			United States				100 Metropolitan Areas			
	U.S.	100 Areas	Part	SO_x	HC	CO	Part	SO_x	HC	CO
Kraft (sulfate) pulp plants	113	16	633	--	--	--	109	--	--	--
Iron and steel plants	141	115	1490	--	--	--	1060	--	--	--
Gray iron foundries	1279	661	217	--	--	3200	94	--	--	1250
Primary nonferrous metallurgical plants	64	12	95	3848	--	--	22	144	--	--
Sulfuric acid plants	212	102	60	750	--	--	40	480	--	--
Phosphate fertilizer plants	171	19	20	--	--	--	11	--	--	--
Petroleum refineries	262	134	96	2100	932[c]	2000	48	923	587[c]	1080
Asphalt batching plants	1500	903	522	--	--	--	206	--	--	--
Cement plants	176	92	908	--	--	--	525	--	--	--
Lime plants	135	67	450	--	--	--	251	--	--	--
Coal cleaning plants	691	109	160	--	--	--	27	--	--	--
Petroleum products storage plants	29,664	6130	--	--	1100	--	--	--	636	--
Grain mills and elevators	14,013	1996	1210	--	--	--	1200	--	--	--
Varnish plants	230	216	--	--	5	--	--	--	5	--
Rubber (tire and inner tube) plants	159	102	--	--	--	--	--	--	--	--
Secondary nonferrous metallurgical plants	793	690	48	--	--	--	45	--	--	--
Totals- -			5919	6708	2037	5200	3638	1547	1228	2330

[a] Totals for facilities in operation in 1967. Blanks in the table indicate the emission levels meet applicable regulations (App. A); levels for rubber plants could not be estimated due to lack of data.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO).

[c] Hydrocarbon emissions from storage evaporation, transfer operations, and catalytic cracking.

In 1975, even with the projected use of low-sulfur content fuel, steam-electric generating stations will continue to account for a similar percentage of emissions from stationary combustion sources.

The largest industrial process source of sulfur oxide emissions studied was petroleum refining, (Table 4-3), followed by sulfuric acid and primary nonferrous metallurgical plants. Since the 1975 control level for petroleum refining was estimated at only 50 percent, this source will account for nearly all of the sulfur oxide emissions from industrial sources.

D. Hydrocarbons

Hydrocarbon emissions from solid waste disposal operations amounted to 160 thousand tons in 1967. Estimated 1975 emissions are 49 thousand tons (Table 4-4).

Good operating practice and maintenance procedures limit hydrocarbon emissions from stationary combustion sources to very low levels; therefore, such emissions were not estimated.

It is estimated that significant hydrocarbon emissions will occur in only three of the industrial processes studied: varnish, petroleum refining, and petroleum storage (Table 4-3). The latter two accounted for approximately 99 percent of the estimated 1967 industrial process emissions.

E. Carbon Monoxide

Carbon monoxide emissions from solid waste disposal operations were 1950 thousand tons in 1967, exceeding both gray iron foundry and petroleum refining emissions.

Carbon monoxide emissions from stationary combustion sources were not estimated, since such emissions are negligible with good operating practices.

Emissions of carbon monoxide were estimated for only two of the industrial process sources, gray iron foundries and petroleum refining; gray iron foundry emissions were greater (see Table 4-3).

III. SOURCE SUMMARY

A. Introduction

The emission estimates presented in Table 4-1 for solid waste disposal, stationary combustion, and industrial process sources are, as mentioned previously, composites representing a number of individual sources. This section presents some of the source estimates upon which Table 4-1 is based.

B. 1967 Emission Levels

Tables 4-2 and 4-3 present 1967 emission estimates for individual sources within the stationary combustion and industrial process source categories. In addition to emissions for the 100 metropolitan areas, estimates are also included for the entire Nation.

C. 1975 Emission Levels

Table 4-4 presents projected emissions by individual source for the year 1975, with and without implementation of the Clean Air Act, as Amended. The emission estimates include emissions from sources in existence in 1967 as well as additional sources assumed to be added between 1967 and 1975. The 1975 emission levels without the Act assume that the sources in existence in 1967 as well as the new sources are controlled at 1967 levels.1/ The 1975 emission levels with the Act assume that both the sources in existence in 1967 and the new sources are controlled to the levels required by the assumed emission standards.

For convenience, total investment (FY 1971-1975) and ultimate annual costs (FY 1975) are also included in Table 4-4.

1/ Control levels, by source and fiscal year, are given in the appropriate appendixes.

Table 4-4

PROJECTED EMISSION LEVELS AND RELATIVE EFFECTS OF THE ACT BY THE END OF FISCAL YEAR 1975[a]
(100 metropolitan areas)

STATIONARY EMISSION SOURCE	1975 EMISSION LEVEL WITHOUT THE ACT[b] (1000 tons/year)				1975 EMISSION LEVEL WITH THE ACT (1000 tons/year)				TOTAL AREA CONTROL COST (million dollars)[c]	
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Inv.	Ult. Ann.
SOLID WASTE DISPOSAL	947	--	204	2089	187	--	49	299	221	107
STATIONARY COMBUSTION										
Steam-electric power plants	2550	8520	--	--	231	3121	--	--	161	786
Industrial boilers	1930	4780	--	--	72	1759	--	--	547	412
Commercial-institutional heating plants	69	736	--	--	31	580	--	--	31	6
Residential heating plants	173	1100	--	--	57	541	--	--	550	129
Totals	4722	15136	--	--	391	6001	--	--	1289	1333
INDUSTRIAL PROCESS										
Kraft (sulfate) pulp plants	164	--	--	--	33	--	--	--	7	3
Iron and steel plants	1420	--	--	--	134	--	--	--	412	263
Gray iron foundries	129	--	--	1720	15	--	--	104	238	78
Primary nonferrous metallurgical plants	29	175	--	--	17	< 5	--	--	81	28
Sulfuric acid plants	55	561	--	--	32	78	--	--	37	3
Phosphate fertilizer plants	16	--	--	--	6	--	--	--	5	2
Petroleum refineries	63	1130	719	1323	34	903	97	124	103	2
Asphalt batching plants	306	--	--	--	122	--	--	--	34	28
Cement plants	723	--	--	--	51	--	--	--	19	6
Lime plants	289	--	--	--	29	--	--	--	1	1
Coal cleaning plants	47	--	--	--	5	--	--	--	3	1
Petroleum products storage plants	--	--	779	--	--	--	419	--	84	0
Grain mills and elevators	1350	--	--	--	20	--	--	--	46	16
Varnish plants	--	--	6	--	--	--	< 2	--	1	1
Rubber (tire and inner tube) plants	--	--	--	--	--	--	--	--	5	5
Secondary nonferrous metallurgical plants	65	--	--	--	4	--	--	--	55	18
Totals	4656	1866	1498	3043	505	987	518	228	1131	455

[a] Clean Air Act, as Amended. Blanks in the table indicate the emission levels meet applicable regulations (App. A); levels for rubber plants could not be estimated due to lack of data.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO).

[c] Projected costs (Inv., Ult. Ann.) are the initial investment expenditure (for purchasing and installing control equipment) and the continuing annual costs (for interest, property taxes, insurance, depreciation, etc., and for operating and maintaining equipment). The 100 areas are defined in Appendix B.

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Appendix A

Assumed Emission Standards

Appendix A

Assumed Emission Standards

I. INTRODUCTION

Under the Clean Air Act, as Amended, air quality standards will be adopted for Air Quality Control Regions (AQCR's), then plans for implementation of the standards will be adopted. Ordinarily, implementation plans must include emission standards intended to permit a region to attain and maintain its established air quality standards. For this report, emission standards were selected without going through the above steps, which would have required many assumptions about air quality standards and a massive computational effort to derive appropriate emission standards for all the 100 metropolitan areas. The emission standards selected for this report are representative of those now used throughout the Nation.

II. STANDARDS FOR PARTICULATES

For process sources, the process weight rate regulation ("process weight regulation") of the San Francisco Bay Area Pollution Control District was used as the basis of control cost estimates. This regulation limits the weight of particulate emissions per hour as a function of the total weight of raw materials introduced into a process operation. This regulation, as shown in Table A-1 was applied to all industrial process sources.

For incinerators, the New York State Incinerator Standard for new units was used. This standard limits total particulate emissions on the basis of mass rate (pounds/hour), rather than concentration. Several areas have adopted a variation of this; the New York State standard for new installations (Figure A-1) was used to determine the control efficiency of incinerators. For fuel-burning equipment, the combustion regulation of the State of Maryland was used (see Figure A-2).

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III. STANDARDS FOR SULFUR OXIDES

For fuel-burning equipment, a regulation based on mass emission rate per million Btu input was used. It allows an emission rate of 1.46 pounds of sulfur dioxide per million Btu input; this limit is based on an equivalent sulfur content of 1.0 percent by weight in coal (1.38 percent by weight in oil). For process sources, a concentration standard of 500 parts per million of sulfur dioxide was used.

IV. STANDARDS FOR HYDROCARBONS

For process sources, cost estimates were based on treatment of all exhaust gases to remove organic material by 90 percent (or more) by weight. For petroleum products storage, it was assumed that all stationary tanks, reservoirs, and containers with more than a 40,000-gallon capacity and a vapor pressure of 1.5 pounds per square inch absolute (or greater) must be equipped with floating roofs, vapor recovery systems, or other equally efficient devices. In addition, it was assumed that submerged filling inlets must be installed on all gasoline storage tanks with a capacity of 250 gallons or more.

V. STANDARDS FOR CARBON MONOXIDE

Costs estimates were based on treatment of all exhaust gases to remove or reduce the weight of carbon monoxide emissions by at least 95 percent.

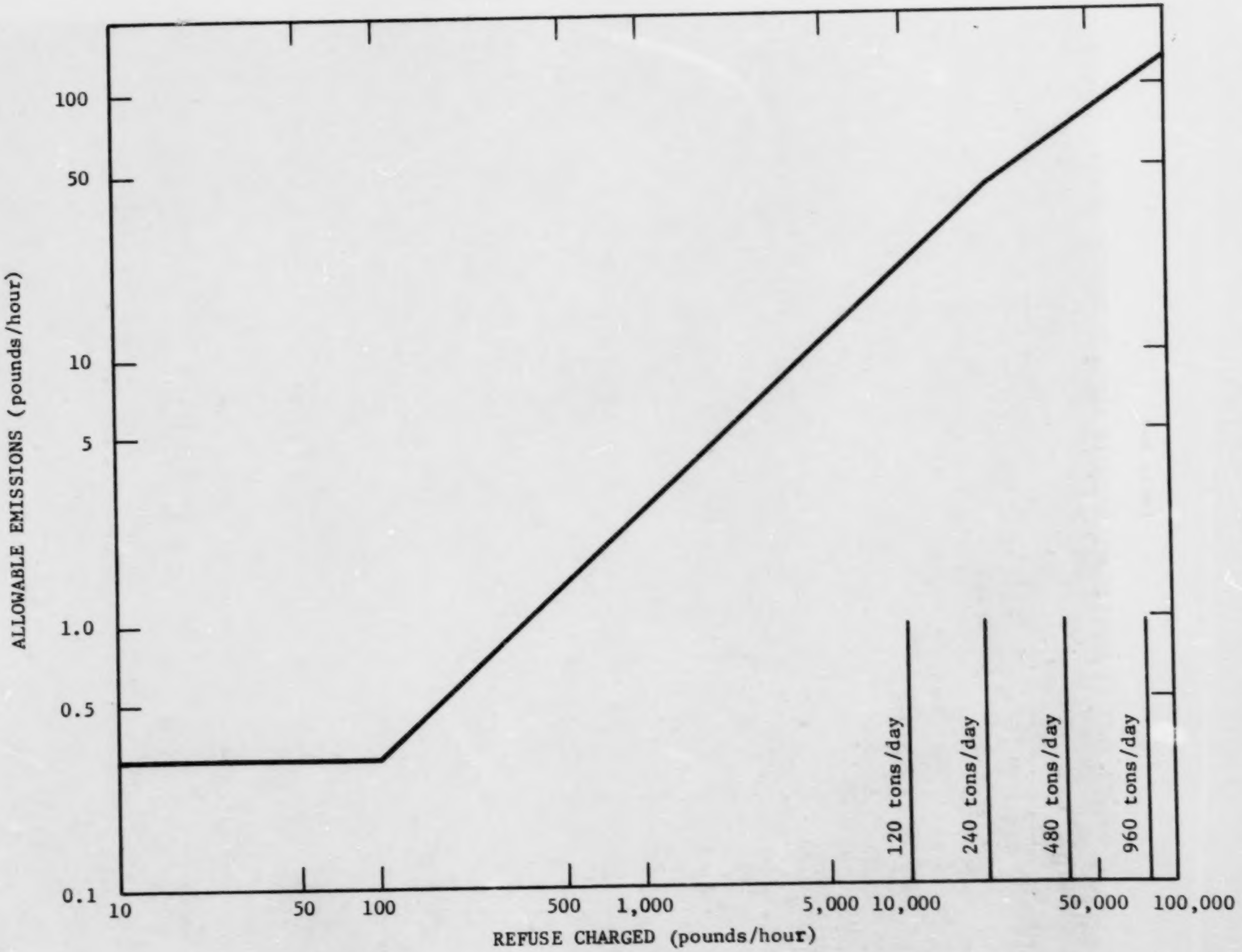

Fig. A-1. New York State Particulate Emission Regulation for Refuse Burning Equipment.

Table A-1

ALLOWABLE RATE OF PARTICULATE EMISSION BASED ON PROCESS WEIGHT RATE[a]

Process Weight Rate		Rate of Emission
Lbs/hr	Tons/hr	Lbs/hr
100	0.05	0.551
200	0.10	0.877
400	0.20	1.40
600	0.30	1.83
800	0.40	2.22
1,000	0.50	2.58
1,500	0.75	3.38
2,000	1.00	4.10
2,500	1.25	4.76
3,000	1.50	5.38
3,500	1.75	5.96
4,000	2.00	6.52
5,000	2.50	7.58
6,000	3.00	8.56
7,000	3.50	9.49
8,000	4.00	10.4
9,000	4.50	11.2
10,000	5.00	12.0
12,000	6.00	13.6
16,000	8.00	16.5
18,000	9.00	17.9
20,000	10.00	19.2
30,000	15.00	25.2
40,000	20.00	30.5
50,000	25.00	35.4
60,000	30.00	40.0
70,000	35.00	41.3
80,000	40.00	42.5
90,000	45.00	43.6
100,000	50.00	44.6
120,000	60.00	46.3
140,000	70.00	47.8
160,000	80.00	49.0
200,000	100.00	51.2
1,000,000	500.00	69.0
2,000,000	1,000.00	77.6
6,000,000	3,000.00	92.7

[a] Data in this table can be interpolated for process weight rates up to 60,000 lb/hr by using equation $E=4.10\ P^{0.67}$ and can be interpolated and extrapolated for process weight rates in excess of 60,000 lb/hr by using equation $E=55.0\ P^{0.11}-40$ (E = rate of emission in lb/hr; P = process weight rate in tons/hr).

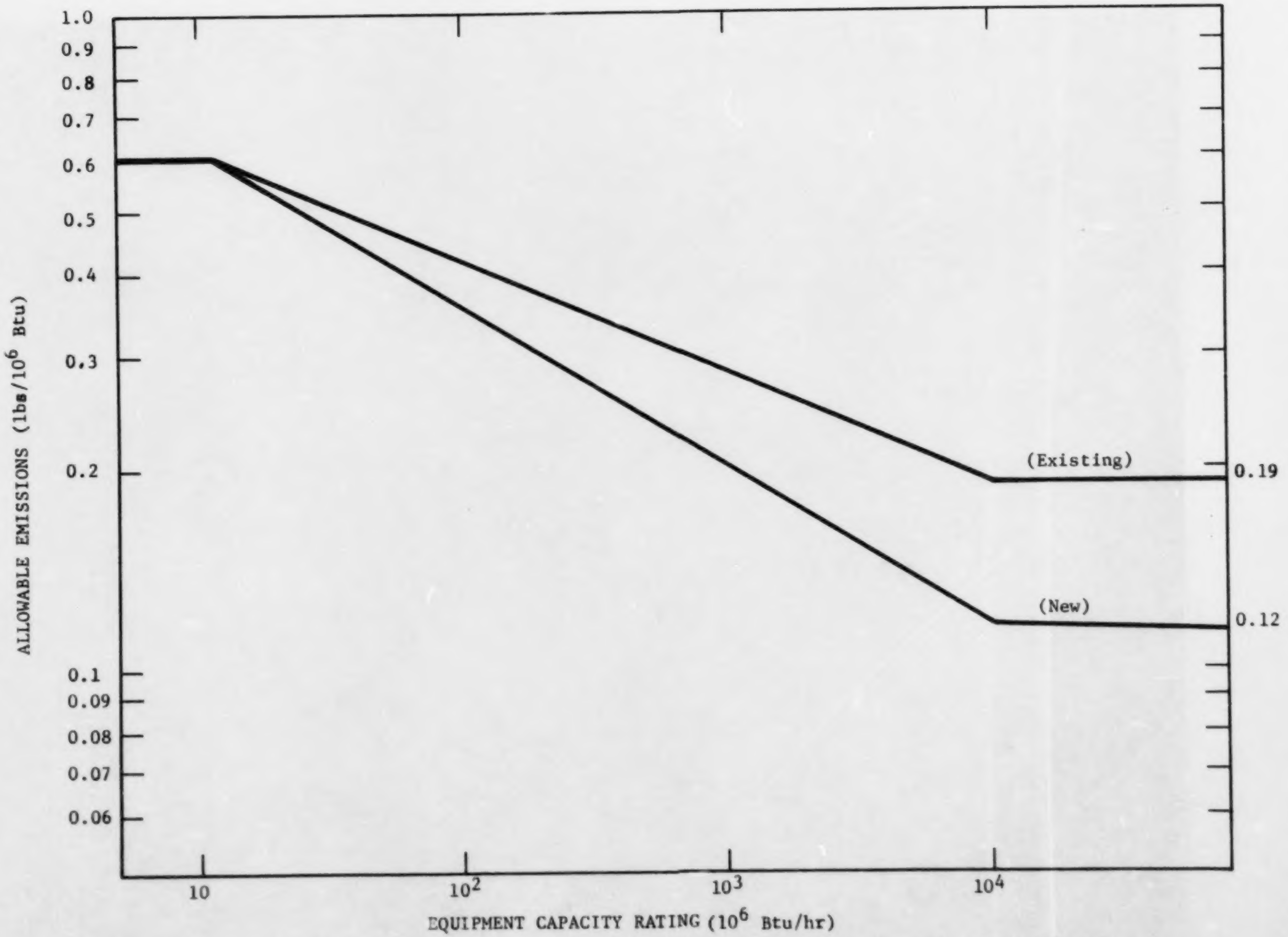

Fig. A-2. Maryland Particulate Emission Standards for Fuel Burning Installations.

Appendix B

Selection of 100 Metropolitan Areas

Appendix B

Selection of 100 Metropolitan Areas

The Clean Air Act, as Amended, specifies a plan for control of air pollution on a regional basis. In brief, after the DHEW has issued air quality criteria and a report on control techniques for a specific type of air pollutant, State governments are expected to adopt and implement air quality standards for that pollutant applicable to the Air Quality Control Regions designated by the Department.

As of June 1, 1969, Air Quality Control Regions (AQCR's) had been designated in 13 metropolitan areas (cities 1-13 in Table B-1). In addition, the central city or cities of each of 44 additional areas had been officially identified as places where regions would be designated by the end of Fiscal Year 1970. Thus, there are 57 areas in which AQCR's either have been or definitely will be designated; however, it is possible that they will be designated in a different order than that given in Table B-1 and that recommendations by States may result in the designation of additional AQCR's before the initial 57 listed are officially designated.

Because this report covers a five-year period ending June 1975, it is likely that more than 57 AQCR's will have been designated by that time; thus 43 other areas are included and estimates of cost are presented for stationary source controls in 100 metropolitan areas.

With respect to their status as actual or projected AQCR's (see Table B-1), the 100 areas can be divided into four groups:

1) Cities 1-13: these areas were officially designated as AQCR's as of June 1, 1969; the Secretary of DHEW announced the boundaries in the Federal Register and sent letters of notice to the respective State governors.
2) Cities 14-18: for these areas, boundaries of AQCR's were proposed as of June 1, 1969, but are not yet officially designated; for these, a Federal Register notice has been published stating what geographic area will be the basis of a consultation with State and local officials.

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3) Cities 19-57: these areas are scheduled to be designated as AQCR's; as of June 1, 1969, boundaries had not been proposed, but NAPCA has identified these 39 central cities as places in which AQCR's will be designated at some time in the future.

4) Cities 58-100: these 43 additional areas were arbitrarily selected for this report. Standard Metropolitan Statistical Area (SMSA) boundaries were assumed and the areas were ranked on the basis of population, estimated emissions, and number of business establishments of the stationary source categories considered in this report; compilation of the areas does not imply intentions on the part of NAPCA to designate or not to designate them as AQCR's. No attempt is made to anticipate choices of areas for designation as AQCR's beyond NAPCA's announced 57, and even if some of these 43 are chosen for designation, official boundaries will not necessarily be the same as those assumed for this report.

Table B-1 was compiled on the basis of information available as of June 1, 1969. Designations, proposals, consultations, other announcements, or other information pertaining to the designation of AQCR's after that date have not been considered in this report.

Table B-1

LIST OF 100 METROPOLITAN AREAS[a]

Air Quality Control Regions - Designated as of June 1, 1969

1. Washington, D. C. (Maryland, Virginia)
2. New York, New York (New Jersey, Delaware)
3. Chicago, Illinois (Indiana)
4. Philadelphia, Pennsylvania (New Jersey, Delaware)
5. Denver, Colorado
6. Los Angeles, California
7. St. Louis, Missouri (Illinois)
8. Boston, Massachusetts
9. San Francisco, California
10. Pittsburgh, Pennsylvania
11. Buffalo, New York
12. Cincinnati, Ohio (Indiana, Kentucky)
13. Cleveland, Ohio

Air Quality Control Regions - Proposed as of June 1, 1969

14. Kansas City, Missouri (Kansas)
15. Baltimore, Maryland
16. Minneapolis-St. Paul, Minnesota
17. Hartford,[b] Connecticut (Massachusetts)
18. Indianapolis, Indiana

Metropolitan Areas - Announced for Designation[c]

19. Detroit, Michigan
20. Milwaukee/Kenosha/Racine, Wisconsin
21. Providence-Pawtucket, Rhode Island/Fall River, Massachusetts
22. Seattle-Everett/Tacoma, Washington
23. Louisville, Kentucky (Indiana)
24. Dayton, Ohio
25. Phoenix, Arizona
26. Houston/Galveston-Texas City, Texas
27. Dallas/Ft. Worth, Texas
28. San Antonio, Texas
29. Birmingham, Alabama
30. Toledo, Ohio (Michigan)
31. Steubenville-Weirton, Ohio/Wheeling, West Virginia
32. Chattanooga, Tennessee (Georgia)
33. Atlanta, Georgia
34. Memphis, Tennessee (Arkansas)
35. Portland, Oregon (Washington)
36. Salt Lake City, Utah
37. New Orleans, Louisiana
38. Miami/Fort Lauderdale, Florida
39. Oklahoma City, Oklahoma
40. Omaha, Nebraska (Iowa)
41. Honolulu, Hawaii
42. Beaumont-Port Arthur-Orange, Texas
43. Charlotte, North Carolina
44. Portland, Maine
45. Albuquerque, New Mexico
46. Lawrence-Haverhill/Lowell, Massachusetts/Manchester, New Hampshire
47. El Paso, Texas
48. Las Vegas, Nevada
49. Fargo-Moorhead, North Dakota, Minnesota

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[a] When a state name is in parentheses, it indicates that the area extends into that State.

[b] Also includes New Haven, Waterbury, and Meridan SMSA's, although not in originally proposed AQCR.

[c] Slashes separate two or more SMSA's which comprise one metropolitan area.

Table B-1 (continued)

Metropolitan Areas - Announced for Designation (continued)

50. Boise, Idaho
51. Billings, Montana
52. Sioux Falls, South Dakota
53. Cheyenne, Wyoming
54. Anchorage, Alaska
55. Burlington, Vermont
56. San Juan, Puerto Rico
57. Virgin Islands

Additional Metropolitan Areas - Selected for this Report[c]

58. Albany-Schenectady-Troy, New York
59. Allentown-Bethlehem-Easton, Pennsylvania, New Jersey
60. Anderson/Muncie, Indiana
61. Bakersfield, California
62. Binghamton, New York (Pennsylvania)
63. Charleston, South Carolina
64. Charleston, West Virginia
65. Columbus, Ohio
66. Davenport-Rock Island-Moline, Iowa, Illinois
67. Des Moines, Iowa
68. Flint, Michigan
69. Fresno, California
70. Fort Wayne, Indiana
71. Grand Rapids/Muskegon-Muskegon Hts., Michigan
72. Greensboro, North Carolina
73. Harrisburg, Pennsylvania
74. Jackson, Mississippi
75. Jacksonville, Florida
76. Johnstown, Pennsylvania
77. Knoxville, Tennessee
78. Lancaster, Pennsylvania
79. Mobile, Alabama
80. Nashville, Tennessee
81. Norfolk-Portsmouth/Newport News-Hampton, Virginia
82. Peoria, Illinois
83. Raleigh/Durham, North Carolina
84. Reading, Pennsylvania
85. Richmond, Virginia
86. Rochester, New York
87. Rockford, Illinois
88. Sacramento, California
89. Saginaw/Bay City, Michigan
90. San Diego, California
91. Scranton/Wilkes Barre-Hazelton, Pennsylvania
92. South Bend, Indiana
93. Syracuse, New York
94. Tampa, Florida
95. Tulsa, Oklahoma
96. Utica-Rome, New York
97. Wichita, Kansas
98. Worcester/Fitchburg-Leominster, Massachusetts
99. York, Pennsylvania
100. Youngstown-Warren, Ohio

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[c] Slashes separate two or more SMSA's which comprise one metropolitan area.

Appendix C

Chronological Phasing of the Implementation of Air Quality Control in 100 Metropolitan Areas

Appendix C

Chronological Phasing of the Implementation of Air Quality Control in 100 Metropolitan Areas

The Clean Air Act, as Amended, sets forth in Section 108, the procedures through which air quality standards are enacted and implemented in Air Quality Control Regions (AQCR's). It is in reducing air pollution to comply with such standards that owners and operators of pollution sources will incur the costs for which estimates are presented in this report.

To make realistic estimates of air pollution control costs for stationary sources in each of the 100 metropolitan areas covered in this report, each area was treated as though it either had been designated as an AQCR or would be so designated on a specific date. It was further assumed that:

1) Air quality criteria and reports on control techniques for sulfur oxides, particulates, carbon monoxide, and hydrocarbons were available on the assumed designation dates.
2) The cognizant State governments will adopt air quality standards and implementation plans in accordance with the time schedule prescribed by Section 108 of the Clean Air Act, as Amended.
3) In general, the installation of controls will be completed no later than three years after the States' implementation plans have been approved by DHEW.

The following schedule is a general representation of the flow of events from the time of the designation of an AQCR to the time at which control is complete:

Day 1	Official designation of boundaries for AQCR's (or already designated AQCR's); the distribution of air quality criteria and reports on control technology by DHEW.
Day 90	Governor of the State(s) in which the AQCR lies files a letter of intent to adopt ambient air quality standards.
Day 270	State(s) adopts AQCR air quality standards consistent with air quality criteria and reports on control technology issued by DHEW; upon issue of control technology documents for other pollutants, AQCR's must adopt other air quality standards for these additional pollutants.

Day 450	State(s) submits a plan to DHEW specifying the methods they will use to implement, maintain, and enforce the air quality standards.
Day 540	DHEW approval of implementation plan.
After 2.5 yrs.	First 25 percent of total control cost incurred.
After 3.5 yrs.	Additional 50 percent of total control cost.
After 4.5 yrs. (Not later than 6/30/75)	Final 25 percent of total control cost.

Compliance with emission standards obviously cannot be achieved immediately upon the adoption of standards, because of such constraints as the limited enforcement agency staff and design, fabrication, and delivery time requirements for control equipment. By similar reasoning, the three-year period was reduced to two and one-half for the last group of cities (Group V below) since some of the earlier limitations will have been reduced by the time control is required for their sources.

Since all facilities will be assumed to be in compliance by the end of Fiscal 1975, all groups listed below will have expended 25 percent of the total investment at the end of the first year after the adoption of standards and 50 percent at the end of the second. Groups I-IV will have expended the final 25 percent during the third year; Group V will have incurred the final 25 percent during the first half of the third year and will be in compliance by the end of Fiscal 1975. Table C-1 lists the areas by groups; Table C-2 gives this scheduling plan in detail.

Table C-1

100 METROPOLITAN AREAS BY GROUPS[a]
(according to designation dates)

Group I (all designated by June 1969)

1. Washington, D. C. (Maryland, Virginia)
2. New York, New York (New Jersey, Delaware)
3. Chicago, Illinois (Indiana)
4. Philadelphia, Pennsylvania (New Jersey, Delaware)
5. Denver, Colorado
6. Los Angeles, California
7. St. Louis, Missouri (Illinois)
8. Boston, Massachusetts
9. San Francisco, California
10. Pittsburgh, Pennsylvania
11. Buffalo, New York
12. Cincinnati, Ohio (Indiana, Kentucky)
13. Cleveland, Ohio

Group II (assumed to be designated by December 1969)

14. Kansas City, Missouri (Kansas)
15. Baltimore, Maryland
16. Minneapolis-St. Paul, Minnesota
17. Hartford[b], Connecticut
18. Indianapolis, Indiana
19. Detroit, Michigan
20. Milwaukee/Kenosha/Racine, Wisconsin
21. Providence-Pawtucket, Rhode Island/ Fall River, Massachusetts
22. Seattle-Everett/Tacoma, Washington
23. Louisville, Kentucky (Indiana)
24. Dayton, Ohio
25. Phoenix, Arizona
26. Houston/Galveston-Texas City, Texas
27. Dallas/Ft. Worth, Texas
28. San Antonio, Texas
29. Birmingham, Alabama
30. Toledo, Ohio (Michigan)
31. Steubenville-Weirton, Ohio/ Wheeling, West Virginia
32. Chattanooga, Tennessee (Georgia)
33. Atlanta, Georgia
34. Memphis, Tennessee (Arkansas)
35. Portland, Oregon (Washington)

Group III (assumed to be designated by June 1970)

36. Salt Lake City, Utah
37. New Orleans, Louisiana
38. Miami/Fort Lauderdale, Florida
39. Oklahoma City, Oklahoma
40. Omaha, Nebraska (Iowa)
41. Honolulu, Hawaii
42. Beaumont-Port Arthur-Orange, Texas
43. Charlotte, North Carolina
44. Portland, Maine
45. Albuquerque, New Mexico
46. Lawrence-Haverhill/ Lowell, Massachusetts /Manchester, New Hampshire
47. El Paso, Texas
48. Las Vegas, Nevada
49. Fargo-Moorhead, North Dakota, Minnesota
50. Boise, Idaho
51. Billings, Montana
52. Sioux Falls, South Dakota
53. Cheyenne, Wyoming
54. Anchorage, Alaska
55. Burlington, Vermont
56. San Juan, Puerto Rico
57. Virgin Islands

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[a] A State name in parenthesis indicates the area extends into that State.

[b] Includes New Haven, Waterbury, and Meridan SMSA's that are not in originally proposed AQCR.

Table C-1 (continued)

Group IV (assumed to be designated by December 1970)

58. Allentown-Bethlehem-Easton, Pennsylvania, New Jersey
59. Anderson/Muncie, Indiana
60. Bakersfield, California
61. Columbus, Ohio
62. Davenport-Rock Island-Moline, Iowa, Illinois
63. Flint, Michigan
64. Grand Rapids/Muskegon-Muskegon Hts., Michigan
65. Greensboro, North Carolina
66. Harrisburg, Pennsylvania
67. Jacksonville, Florida
68. Knoxville, Tennessee
69. Nashville, Tennessee
70. Peoria, Illinois
71. Richmond, Virginia
72. Rochester, New York
73. Saginaw/Bay City, Michigan
74. Scranton/Wilkes Barre-Hazelton, Pennsylvania
75. Syracuse, New York
76. Tampa, Florida
77. Tulsa, Oklahoma
78. Worcester/Fitchburg-Leominster, Massachusetts
79. Youngstown-Warren, Ohio

Group V (assumed to be designated by June 1971)

80. Albany-Schenectady-Troy, New York
81. Binghamton, New York (Pennsylvania)
82. Charleston, South Carolina
83. Charleston, West Virginia
84. Des Moines, Iowa
85. Fresno, California
86. Fort Wayne, Indiana
87. Jackson, Mississippi
88. Johnstown, Pennsylvania
89. Lancaster, Pennsylvania
90. Mobile, Alabama
91. Norfolk-Portsmouth/Newport News-Hampton, Virginia
92. Raleigh/Durham, North Carolina
93. Reading, Pennsylvania
94. Rockford, Illinois
95. Sacramento, California
96. San Diego, California
97. South Bend, Indiana
98. Utica-Rome, New York
99. Wichita, Kansas
100. York, Pennsylvania

Table C-2

IMPLEMENTATION SCHEDULE FOR 100 METROPOLITAN AREAS BY GROUP

STEPS IN IMPLEMENTING THE CLEAN AIR ACT, AS AMENDED	EXPECTED DATES OF EVENTS BY AREA GROUPS[a]					
	Group I		Group II	Group III	Group IV	Group V
	(Part, SO_x)	(HC, CO)	(Part, SO_x, HC, CO)			
Day 1: designation of AQCR[b]	6/1969	1/1970	12/1969	6/1970	12/1970	6/1971
Day 90: submit letter of intent	9/1969	3/1970	3/1970	9/1970	3/1971	9/1971
Day 270: adopt standard	3/1970	9/1970	9/1970	3/1971	9/1971	3/1972
Day 450: submit implementation plan	9/1970	3/1971	3/1971	9/1971	3/1972	9/1972
Day 540 : DHEW approval of implementation plan[c]	12/1970	6/1971	6/1971	12/1971	6/1972	12/1972
ACCUMULATED RATES OF EXPENDITURES						
After 2½ yrs: 25% of total investment incurred	12/1971	6/1972	6/1972	12/1972	6/1973	12/1973
After 3½ yrs: 50% of total investment incurred	12/1972	6/1973	6/1973	12/1973	6/1974	12/1974
After 4½ yrs: 100% of total investment incurred[d]	12/1973	6/1974	6/1974	12/1974	6/1975	6/1975

[a] For Group I, particulate and sulfur oxide control will precede hydrocarbon and carbon monoxide control by 6 months due to January 1970 publication of control and criteria report; for Groups II-V, planning the control of all four pollutants is expected to begin with Day 1 (Designation).

[b] Or the date of publication of criteria and control technology reports, whichever is later.

[c] Assumed period of 90 days for DHEW approval.

[d] Not later than 6/1975.

Appendix D

1967 Base Year Air Quality Control Costs Annual and Investment Costs by Metropolitan Area, FY 1971-1975

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Appendix D

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
GROUP I:													
1. Washington													
	FY 71	0.1	--	5.4	3.2	0.4	0.3	4.4	2.7	5.9	3.5	7.8	4.4
	FY 72	0.4	0.1	16.1	12.9	1.3	1.0	12.2	10.9	17.8	14.1	23.6	17.7
	FY 73	0.6	0.3	16.1	22.6	1.2	1.8	13.4	19.1	17.9	24.7	23.8	31.0
	FY 74	0.2	0.4	5.4	25.8	0.4	2.1	4.5	21.9	6.0	28.3	8.0	35.6
	FY 75	0.0	0.4	0.0	25.8	0.0	2.1	0.0	21.9	0.0	28.3	0.0	35.6
	Total	1.3	1.3	43.0	90.3	3.3	7.3	35.6	76.5	47.6	98.9	63.2	124.3
2. New York													
	FY 71	2.1	0.7	11.1	10.0	2.1	1.3	10.0	8.9	15.3	12.0	17.4	14.4
	FY 72	8.2	3.0	33.2	39.9	6.4	5.3	31.3	35.7	47.8	48.2	54.5	57.8
	FY 73	10.1	5.5	33.2	69.9	6.4	9.3	32.5	62.7	49.7	84.7	56.7	101.6
	FY 74	4.0	6.3	11.1	79.8	2.1	10.6	11.3	71.6	17.2	96.7	19.6	116.0
	FY 75	0.0	6.3	0.0	79.8	0.0	10.6	0.0	71.6	0.0	96.7	0.0	116.0
	Total	24.4	21.8	88.6	279.4	17.0	37.1	85.1	250.5	130.0	338.3	148.2	405.8
3. Chicago													
	FY 71	10.2	6.1	14.9	21.6	1.9	0.9	18.6	20.9	27.0	28.6	37.3	37.5
	FY 72	33.7	24.4	44.6	86.6	5.7	3.5	58.0	83.6	84.0	114.5	115.9	150.0
	FY 73	36.6	42.7	44.6	151.5	5.6	6.0	60.0	146.1	86.8	200.2	119.8	262.3
	FY 74	13.2	48.9	14.9	173.2	1.9	6.9	20.7	167.2	30.0	229.0	41.4	300.0
	FY 75	0.0	48.9	0.0	173.2	0.0	6.9	0.0	167.2	0.0	229.0	0.0	300.0
	Total	93.7	171.0	119.0	606.1	15.1	24.2	157.3	585.0	227.8	801.3	314.6	1049.8
4. Philadelphia													
	FY 71	4.6	1.8	5.4	5.1	0.4	0.2	8.3	5.2	10.4	7.1	17.2	9.2
	FY 72	16.4	7.2	16.2	20.4	1.3	0.8	27.1	20.7	33.9	28.4	55.9	36.9
	FY 73	18.9	12.7	16.2	35.7	1.2	1.4	29.0	36.4	36.3	49.8	59.9	64.7
	FY 74	7.1	14.6	5.4	40.8	0.4	1.6	10.3	41.6	12.9	57.0	21.3	74.1
	FY 75	0.0	14.6	0.0	40.8	0.0	1.6	0.0	41.6	0.0	57.0	0.0	74.1
	Total	47.0	50.9	43.2	142.8	3.3	5.6	74.7	145.5	93.5	199.3	154.3	259.0
5. Denver													
	FY 71	0.4	0.2	0.6	2.0	0.8	0.3	1.2	2.0	1.8	2.5	2.4	3.1
	FY 72	1.5	0.7	1.8	7.8	2.2	1.1	3.8	7.5	5.5	9.6	7.4	11.9
	FY 73	1.7	1.2	1.8	13.7	2.2	1.9	4.0	13.1	5.7	16.8	7.7	20.8
	FY 74	0.6	1.4	0.6	15.6	0.8	2.1	1.4	14.9	2.0	19.1	2.7	23.7
	FY 75	0.0	1.4	0.0	15.6	0.0	2.1	0.0	14.9	0.0	19.1	0.0	23.7
	Total	4.2	4.9	4.8	54.7	6.0	7.5	10.4	52.4	15.0	67.1	20.2	83.2
6. Los Angeles													
	FY 71	2.4	1.0	--	0.7	--	--	1.6	1.2	2.4	1.7	3.2	2.3
	FY 72	7.2	4.1	--	1.9	--	--	4.7	4.1	7.2	6.0	9.6	8.0
	FY 73	7.2	7.2	--	3.3	--	--	4.7	7.3	7.2	10.5	9.6	14.0
	FY 74	2.3	8.2	--	3.8	--	--	1.5	8.3	2.3	12.0	3.1	16.0
	FY 75	0.0	8.2	--	3.8	--	--	0.0	8.3	0.0	12.0	0.0	16.0
	Total	19.1	28.7	--	13.5	--	--	12.5	29.2	19.1	42.2	25.5	56.3

--Negligible but non-zero expenditure required.
* No additional expenditure required.

See footnotes at end of table.

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Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
7. St. Louis	FY 71	2.0	0.8	6.3	8.1	0.5	0.2	6.2	6.7	8.8	9.1	12.4	11.9
	FY 72	7.4	3.4	19.1	32.5	1.4	0.7	19.6	26.8	27.9	36.6	39.4	47.9
	FY 73	8.8	6.0	19.0	56.9	1.3	1.1	20.5	46.9	29.1	64.0	41.0	83.8
	FY 74	3.4	6.9	6.3	65.7	0.5	1.3	7.2	54.2	10.2	73.9	14.4	96.8
	FY 75	0.0	6.9	0.0	65.7	0.0	1.3	0.0	54.2	0.0	73.9	0.0	96.8
	Total	21.6	24.0	50.7	228.9	3.7	4.6	53.5	188.8	76.0	257.5	107.2	337.2
8. Boston	FY 71	0.5	0.2	2.3	7.8	0.9	0.4	2.7	6.3	3.7	8.4	5.0	9.5
	FY 72	2.1	0.7	6.8	3.1	2.7	1.7	8.3	4.1	11.6	5.5	15.5	6.2
	FY 73	2.5	1.2	6.7	5.5	2.7	3.0	8.6	7.3	11.9	9.7	15.9	11.0
	FY 74	1.0	1.4	2.3	6.3	0.9	3.4	3.0	8.3	4.2	11.1	5.6	12.5
	FY 75	0.0	1.4	0.0	6.3	0.0	3.4	0.0	8.3	0.0	11.1	0.0	12.5
	Total	6.1	4.9	18.1	29.0	7.2	11.9	22.6	34.3	31.4	45.8	42.0	51.7
9. San Francisco	FY 71	1.1	0.4	--	0.2	--	--	0.7	0.4	1.1	0.6	1.5	0.8
	FY 72	3.2	1.6	--	0.9	--	--	2.1	1.6	3.2	2.5	4.4	3.4
	FY 73	3.2	2.8	--	1.6	--	--	2.1	2.9	3.2	4.4	4.4	6.0
	FY 74	1.1	3.2	--	1.9	--	--	0.7	3.3	1.1	5.1	1.5	7.0
	FY 75	0.0	3.2	--	1.9	--	--	0.0	3.3	0.0	5.1	0.0	7.0
	Total	8.6	11.2	--	6.5	--	--	5.6	11.5	8.6	17.7	11.8	24.2
10. Pittsburgh	FY 71	7.4	4.7	4.9	5.2	0.9	0.4	9.4	7.4	13.2	10.3	17.4	13.4
	FY 72	22.6	18.7	14.8	20.8	2.8	1.6	28.5	29.6	40.2	41.1	53.1	53.4
	FY 73	23.0	32.6	14.8	36.5	2.8	2.8	28.7	51.8	40.6	71.9	53.6	93.5
	FY 74	7.8	37.4	4.9	41.7	0.9	3.2	9.6	59.3	13.6	82.3	18.0	107.0
	FY 75	0.0	37.4	0.0	41.7	0.0	3.2	0.0	59.3	0.0	82.3	0.0	107.0
	Total	60.8	130.8	39.4	145.9	7.4	11.2	76.2	207.4	107.6	287.9	142.1	374.3
11. Buffalo	FY 71	3.0	1.7	5.7	2.7	0.4	0.2	6.5	3.2	9.1	4.6	12.3	6.4
	FY 72	9.3	6.7	17.3	10.9	1.3	0.8	19.8	12.9	27.9	18.4	37.7	25.4
	FY 73	9.7	11.8	17.2	19.1	1.2	1.4	19.9	22.6	28.1	32.3	37.9	44.6
	FY 74	3.4	13.5	5.7	21.9	0.4	1.6	6.7	25.9	9.5	37.0	12.8	51.1
	FY 75	0.0	13.5	0.0	21.9	0.0	1.6	0.0	25.9	0.0	37.0	0.0	51.1
	Total	25.4	47.2	45.9	76.5	3.3	5.6	52.9	90.5	74.6	129.3	100.7	178.6
12. Cincinnati	FY 71	2.0	0.6	3.9	4.9	0.5	0.2	4.9	4.6	6.4	5.7	8.6	7.7
	FY 72	7.4	2.5	11.8	19.7	1.5	1.0	15.9	18.6	20.7	23.2	27.9	31.3
	FY 73	8.9	4.6	11.8	34.4	1.4	1.7	17.0	32.7	22.1	40.7	29.8	54.9
	FY 74	3.5	5.4	3.9	39.3	0.5	1.9	6.1	37.4	7.9	46.6	10.7	62.9
	FY 75	0.0	5.4	0.0	39.3	0.0	1.9	0.0	37.4	0.0	46.6	0.0	62.9
	Total	21.8	18.5	31.4	137.6	3.9	6.7	43.9	130.7	57.1	162.8	77.0	219.7
13. Cleveland	FY 71	4.7	2.2	5.0	4.8	1.2	0.5	7.6	5.3	10.9	7.5	14.7	10.1
	FY 72	14.8	8.9	14.9	19.0	3.4	2.0	23.0	21.3	33.1	29.9	44.7	40.4
	FY 73	15.4	15.6	14.9	33.3	3.4	3.5	23.4	37.3	33.7	52.4	45.5	70.7
	FY 74	5.3	17.9	5.0	38.0	1.2	4.0	8.0	42.6	11.5	59.9	15.5	80.9
	FY 75	0.0	17.9	0.0	38.0	0.0	4.0	0.0	42.6	0.0	59.9	0.0	80.9
	Total	40.2	62.5	39.8	133.1	9.2	14.0	62.0	149.1	89.2	209.6	120.4	283.0

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
GROUP II:													
14. Kansas City													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	3.5	0.6	0.7	1.6	0.1	0.1	2.1	1.8	3.3	2.3	4.8	3.0
	FY 73	5.1	2.0	1.5	4.9	0.2	0.4	4.3	5.5	6.8	7.3	9.7	9.1
	FY 74	2.5	2.7	0.8	6.6	0.1	0.5	2.2	7.3	3.4	9.8	4.8	12.1
	FY 75	0.0	2.7	0.0	6.6	0.0	0.5	0.0	7.3	0.0	9.8	0.0	12.1
	Total	10.1	8.0	3.0	19.7	0.4	1.5	8.6	21.9	13.5	29.2	19.3	36.3
15. Baltimore													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	5.6	2.7	3.8	3.7	1.3	0.6	7.7	5.2	10.7	7.0	13.9	8.8
	FY 73	11.2	8.1	7.5	11.2	2.7	1.7	15.4	15.6	21.4	21.0	27.8	26.5
	FY 74	5.6	10.8	3.8	15.0	1.3	2.3	7.7	20.9	10.7	28.1	13.9	35.4
	FY 75	0.0	10.8	0.0	15.0	0.0	2.3	0.0	20.9	0.0	28.1	0.0	35.4
	Total	22.4	32.4	15.1	44.9	5.3	6.9	30.8	62.6	42.8	84.2	55.6	106.1
16. Minneapolis-St. Paul													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	3.3	1.2	3.7	3.1	1.3	0.5	5.7	3.6	8.3	4.8	11.5	6.0
	FY 73	6.7	3.5	7.5	9.3	2.6	1.6	11.6	10.8	16.8	14.4	23.4	18.0
	FY 74	3.4	4.7	3.7	12.5	1.3	2.1	5.8	14.5	8.4	19.3	11.7	24.1
	FY 75	0.0	4.7	0.0	12.5	0.0	2.1	0.0	14.5	0.0	19.3	0.0	24.1
	Total	13.4	14.1	14.9	37.4	5.2	6.3	23.1	43.4	33.5	57.8	46.6	72.2
17. Hartford[b]													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.5	0.5	1.7	2.4	1.6	0.7	3.3	2.7	4.8	3.6	6.5	4.5
	FY 73	3.2	1.5	3.4	7.3	3.1	2.1	6.7	8.2	9.7	10.9	13.1	13.6
	FY 74	1.5	2.1	1.7	9.7	1.6	2.8	3.4	11.0	4.8	14.6	6.5	18.3
	FY 75	0.0	2.1	0.0	9.7	0.0	2.8	0.0	11.0	0.0	14.6	0.0	18.3
	Total	6.2	6.2	6.8	29.1	6.3	8.4	13.4	32.9	19.3	43.7	26.1	54.7
18. Indianapolis													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.3	0.4	4.2	3.2	0.8	0.3	4.4	2.8	6.3	3.9	8.7	5.2
	FY 73	2.6	1.0	8.3	9.5	1.5	1.0	8.7	8.3	12.4	11.5	17.1	15.4
	FY 74	1.3	1.3	4.2	12.7	0.8	1.3	4.4	11.1	6.3	15.3	8.7	20.5
	FY 75	0.0	1.3	0.0	12.7	0.0	1.3	0.0	11.1	0.0	15.3	0.0	20.5
	Total	5.2	4.0	16.7	38.1	3.1	3.9	17.5	33.3	25.0	46.0	34.5	61.6
19. Detroit													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	8.2	3.5	9.9	17.4	2.4	1.1	14.5	15.9	20.5	22.0	27.7	29.5
	FY 73	16.4	10.5	19.8	52.2	4.6	3.2	28.8	47.5	40.8	65.9	55.1	88.3
	FY 74	8.2	14.0	9.9	69.6	2.4	4.3	14.5	63.4	20.5	87.9	27.7	117.8
	FY 75	0.0	14.0	0.0	69.6	0.0	4.3	0.0	63.4	0.0	87.9	0.0	117.8
	Total	32.8	42.0	39.6	208.8	9.4	12.9	57.8	190.2	81.8	263.7	110.5	353.4

See footnotes at end of table.

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
20. Milwaukee/Kenosha/Racine													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	2.2	0.6	10.9	8.1	1.0	0.5	8.9	6.9	14.1	9.2	17.2	11.9
	FY 73	4.4	1.8	21.7	24.2	2.1	1.4	17.9	20.6	28.2	27.4	34.4	35.3
	FY 74	2.2	2.4	10.9	32.3	1.0	1.8	8.9	27.4	14.1	36.5	17.2	47.1
	FY 75	0.0	2.4	0.0	32.3	0.0	1.8	0.0	27.4	0.0	36.5	0.0	47.1
	Total	8.8	7.2	43.5	96.9	4.1	5.5	35.7	82.3	56.4	109.6	68.8	141.4
21. Providence-Pawtuckett/Fall River													
	FY 71	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.6	0.4	--	0.7	0.6	0.3	1.5	1.3	2.2	1.4	2.9	1.8
	FY 73	3.1	1.3	--	2.1	1.3	0.8	3.0	3.8	4.4	4.2	5.9	5.2
	FY 74	1.6	1.7	--	2.8	0.6	1.1	1.5	5.1	2.2	5.6	2.9	7.0
	FY 75	0.0	1.7	--	2.8	0.0	1.1	0.0	5.1	0.0	5.6	0.0	7.0
	Total	6.3	5.1	--	8.4	2.5	3.3	6.0	15.3	8.8	16.8	11.7	21.0
22. Seattle-Everett/Tacoma													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	3.5	1.3	0.1	--	0.1	0.1	2.2	0.8	3.7	1.4	5.0	1.8
	FY 73	7.1	4.0	2.3	-0.1	0.3	0.4	4.5	2.4	9.7	4.3	10.1	5.5
	FY 74	3.6	5.3	0.1	-0.1	0.2	0.6	2.3	3.3	3.8	5.8	5.0	7.3
	FY 75	0.0	5.3	0.0	-0.1	0.0	0.6	0.0	3.3	0.0	5.8	0.0	7.3
	Total	14.2	15.9	2.5	-0.3	0.6	1.7	9.0	9.8	17.2	17.3	20.1	21.9
23. Louisville													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.2	0.4	4.8	9.8	0.4	0.2	4.5	7.8	6.4	10.4	8.8	13.5
	FY 73	2.3	1.1	9.5	19.6	0.9	0.7	8.9	16.1	12.7	21.4	17.4	27.8
	FY 74	1.1	1.4	4.8	39.2	0.5	0.9	4.5	31.1	6.4	41.5	8.8	53.9
	FY 75	0.0	1.4	0.0	39.2	0.0	0.9	0.0	31.1	0.0	41.5	0.0	53.9
	Total	4.6	4.3	19.1	107.8	1.8	2.7	17.9	86.1	25.5	114.8	35.0	149.1
24. Dayton													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.1	0.3	2.9	3.0	0.6	0.2	3.2	2.6	4.6	3.5	6.3	4.6
	FY 73	2.2	0.9	5.8	8.9	1.2	0.7	6.4	7.8	9.2	10.5	12.7	13.7
	FY 74	1.1	1.3	2.9	11.8	0.6	1.0	3.2	10.4	4.6	14.1	6.3	18.2
	FY 75	0.0	1.3	0.0	11.8	0.0	1.0	0.0	10.4	0.0	14.1	0.0	18.2
	Total	4.4	3.8	11.6	35.5	2.4	2.9	12.8	31.2	18.4	42.2	25.3	54.7
25. Phoenix													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.5	0.2	4.7	0.1	--	--	3.3	0.2	5.2	0.3	7.7	0.5
	FY 73	1.0	0.5	9.3	0.3	0.2	0.2	6.6	0.7	10.5	1.0	15.5	1.5
	FY 74	0.5	0.7	4.7	0.3	0.1	0.3	3.3	0.9	5.3	1.3	7.7	2.0
	FY 75	0.0	0.7	0.0	0.3	0.0	0.3	0.0	0.9	0.0	1.3	0.0	2.0
	Total	2.0	2.1	18.7	1.0	0.3	0.8	13.2	2.7	21.0	3.9	30.9	6.0

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]

(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
26. Houston/Galveston-Texas City	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	8.4	1.9	3.1	0.8	1.3	0.6	8.6	2.3	12.8	3.3	18.9	4.2
	FY 73	16.9	5.6	6.2	2.3	2.5	1.7	17.1	6.8	25.6	9.6	37.9	12.5
	FY 74	8.5	7.4	3.1	3.1	1.3	2.3	8.6	9.1	12.9	12.8	18.9	16.7
	FY 75	0.0	7.4	0.0	3.1	0.0	2.3	0.0	9.1	0.0	12.8	0.0	16.7
	Total	33.8	22.3	12.4	9.3	5.1	6.9	34.3	27.3	51.3	38.5	75.7	50.1
27. Dallas/Ft. Worth	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.9	0.5	2.3	0.6	0.1	0.2	3.3	0.9	4.3	1.3	5.7	1.7
	FY 73	3.9	1.6	4.7	1.8	0.4	0.6	6.6	2.8	9.0	4.0	11.4	5.0
	FY 74	1.9	2.1	2.3	2.3	0.2	0.8	3.3	3.8	4.4	5.2	5.7	6.7
	FY 75	0.0	2.1	0.0	2.3	0.0	0.8	0.0	3.8	0.0	5.2	0.0	6.7
	Total	7.7	6.3	9.3	7.0	0.7	2.4	13.2	11.3	17.7	15.7	22.8	20.1
28. San Antonio	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.5	0.2	0.8	0.2	--	--	1.0	0.3	1.3	0.4	1.8	0.6
	FY 73	1.1	0.5	1.6	0.6	0.2	0.2	2.0	1.0	2.9	1.3	3.6	1.7
	FY 74	0.5	0.6	0.9	0.8	0.1	0.3	1.0	1.3	1.5	1.7	1.8	2.2
	FY 75	0.0	0.6	0.0	0.8	0.0	0.3	0.0	1.3	0.0	1.7	0.0	2.2
	Total	2.1	1.9	3.3	2.4	0.3	0.8	4.0	3.9	5.7	5.1	7.2	6.7
29. Birmingham	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	5.1	2.5	1.3	5.3	--	--	4.6	6.0	6.4	7.8	8.4	9.9
	FY 73	10.1	7.6	2.7	15.9	0.1	0.1	9.1	18.1	12.9	23.6	16.8	29.6
	FY 74	5.1	10.2	1.3	21.3	0.1	0.2	4.6	24.1	6.5	31.7	8.4	39.5
	FY 75	0.0	10.2	0.0	21.3	0.0	0.2	0.0	24.1	0.0	31.7	0.0	39.5
	Total	20.3	30.5	5.3	63.8	0.2	0.5	18.3	72.3	25.8	94.8	33.6	118.5
30. Toledo	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.7	0.2	1.5	3.5	--	--	2.1	3.0	3.2	3.7	4.7	4.6
	FY 73	3.3	0.8	2.9	10.4	0.1	0.2	4.2	9.0	6.3	11.4	9.4	13.8
	FY 74	1.7	1.0	1.5	13.9	0.1	0.3	2.1	12.0	3.3	15.2	4.7	18.4
	FY 75	0.0	1.0	0.0	13.9	0.0	0.3	0.0	12.0	0.0	15.2	0.0	18.4
	Total	6.7	3.0	5.9	41.7	0.2	0.8	8.4	36.0	12.8	45.5	18.8	55.2
31. Steubenville/Wierton/Wheeling	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	5.3	3.1	6.2	10.8	--	--	8.3	10.5	11.5	13.9	15.2	17.6
	FY 73	10.6	9.3	12.3	32.3	0.1	0.1	16.9	31.5	23.0	41.7	30.4	52.7
	FY 74	5.2	12.3	6.2	43.1	--	0.1	8.3	42.0	11.4	55.5	15.2	70.2
	FY 75	0.0	12.3	0.0	43.1	0.0	0.1	0.0	42.0	0.0	55.5	0.0	70.2
	Total	21.1	37.0	24.7	129.3	0.1	0.3	33.5	126.0	45.9	166.6	60.8	210.7

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
32. Chattanooga													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.9	0.3	0.3	0.1	--	--	0.8	0.3	1.2	0.4	1.7	0.6
	FY 73	1.9	0.9	0.5	0.4	0.1	0.1	1.7	0.9	2.5	1.4	3.4	1.8
	FY 74	1.0	1.1	0.3	0.5	--	0.1	0.8	1.1	1.3	1.7	1.7	2.4
	FY 75	0.0	1.1	0.0	0.5	0.0	0.1	0.0	1.1	0.0	1.7	0.0	2.4
	Total	3.8	3.4	1.1	1.5	0.1	0.3	3.3	3.4	5.0	5.2	6.8	7.2
33. Atlanta													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.1	0.3	0.8	2.2	0.8	0.4	1.9	2.2	2.7	2.9	3.5	3.5
	FY 73	2.1	1.0	1.5	6.7	1.7	1.1	3.8	6.8	5.3	8.8	6.9	10.7
	FY 74	1.1	1.3	0.8	9.0	0.8	1.5	1.9	9.1	2.7	11.8	3.5	14.3
	FY 75	0.0	1.3	0.0	9.0	0.0	1.5	0.0	9.1	0.0	11.8	0.0	14.3
	Total	4.3	3.9	3.1	26.9	3.3	4.5	7.6	27.2	10.7	35.3	13.9	42.8
34. Memphis													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.8	0.2	0.2	-0.1	--	--	0.7	0.1	1.0	0.1	1.4	0.1
	FY 73	1.6	0.7	0.5	-0.2	0.1	0.2	1.5	0.4	2.2	0.7	3.1	0.9
	FY 74	0.8	0.9	0.2	-0.3	0.1	0.3	0.8	0.5	1.1	0.9	1.6	1.2
	FY 75	0.0	0.9	0.0	-0.3	0.0	0.3	0.0	0.5	0.0	0.9	0.0	1.2
	Total	3.2	2.7	0.9	-0.9	0.2	0.8	3.0	1.5	4.3	2.6	6.1	3.4
35. Portland													
	FY 71	0.0	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	4.8	1.7	0.1	--	0.7	0.3	3.2	1.1	5.6	2.0	6.9	2.5
	FY 73	9.5	4.9	0.1	--	1.4	0.8	6.1	3.2	10.9	5.7	13.5	7.0
	FY 74	4.7	6.6	0.1	--	0.7	1.1	3.1	4.3	5.5	7.7	6.8	9.5
	FY 75	0.0	6.6	0.0	--	0.0	1.1	0.0	4.3	0.0	7.7	0.0	9.5
	Total	19.0	19.8	0.3	--	2.8	3.3	12.4	12.9	22.0	23.1	27.2	28.5

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
Group III													
36. Salt Lake City													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.9	0.4	1.3	0.4	0.2	0.1	1.4	0.5	2.4	0.9	3.3	1.1
	FY 73	2.4	1.7	3.7	1.4	0.7	0.3	4.4	2.0	6.8	3.4	9.9	4.5
	FY 74	2.5	2.9	3.7	2.5	0.8	0.5	4.4	3.6	7.0	5.9	10.1	7.9
	FY 75	0.9	3.3	1.3	2.9	0.2	0.6	1.5	4.1	2.4	6.8	3.3	9.0
	Total	6.7	8.3	10.0	7.2	1.9	1.5	11.7	10.2	18.6	17.0	26.6	22.5
37. New Orleans													
	FY 71	0.0	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	4.1	1.0	--	--	0.2	0.2	2.2	0.7	4.3	1.2	5.3	1.5
	FY 73	12.4	3.9	--	--	0.6	0.6	6.7	2.4	13.0	4.5	16.1	5.5
	FY 74	12.4	6.8	--	--	0.6	1.1	6.7	4.3	13.0	7.9	16.1	9.6
	FY 75	4.2	7.7	--	--	0.2	1.3	2.3	4.9	4.4	9.0	5.5	11.0
	Total	33.1	19.4	--	--	1.6	3.2	17.9	12.3	34.7	22.6	43.0	27.6
38. Miami/Fort Lauderdale													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.4	0.1	0.1	--	0.4	0.2	0.4	0.2	0.9	0.3	1.1	0.5
	FY 73	1.4	0.3	0.2	0.2	1.1	0.9	1.4	1.0	2.7	1.4	3.4	1.8
	FY 74	1.4	0.4	0.1	0.3	1.2	1.6	1.4	1.7	2.7	2.3	3.5	2.9
	FY 75	0.4	0.5	--	0.3	0.4	1.8	0.4	1.9	0.8	2.6	1.1	3.3
	Total	3.6	1.3	0.4	0.8	3.1	4.5	3.6	4.8	7.1	6.6	9.1	8.5
39. Oklahoma City													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.2	0.1	1.6	0.3	--	--	1.2	0.3	1.8	0.4	2.7	0.6
	FY 73	0.6	0.3	4.8	1.1	0.1	0.1	3.6	1.0	5.5	1.5	8.2	2.2
	FY 74	0.6	0.4	4.8	1.9	0.1	0.2	3.6	1.6	5.5	2.5	8.2	3.7
	FY 75	0.2	0.5	1.7	2.2	--	0.2	1.2	1.9	1.9	2.9	2.8	4.3
	Total	1.6	1.3	12.9	5.5	0.2	0.5	9.6	4.8	14.7	7.3	21.9	10.8
40. Omaha													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.4	0.1	1.6	0.7	--	--	1.4	0.6	2.0	0.8	2.8	1.0
	FY 73	1.0	0.4	4.8	2.7	0.1	0.1	4.0	2.4	5.9	3.2	8.4	4.1
	FY 74	1.0	0.7	4.8	4.8	0.1	0.2	4.0	4.2	5.9	5.7	8.4	7.4
	FY 75	0.4	0.8	1.6	5.5	--	0.2	1.4	4.8	2.0	6.5	2.8	8.4
	Total	2.8	2.0	12.8	13.7	0.2	0.5	10.8	12.0	15.8	16.2	22.4	20.9
41. Honolulu													
	FY 71	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.2	0.1	--	0.2	0.3	0.1	0.3	0.2	0.5	0.4	0.6	0.5
	FY 73	0.5	0.2	--	0.9	0.8	0.4	0.9	0.9	1.3	1.5	1.7	1.9
	FY 74	0.5	0.3	--	1.5	0.8	0.7	0.9	1.4	1.3	2.5	1.7	3.1
	FY 75	0.2	0.3	--	1.7	0.3	0.8	0.3	2.2	0.5	2.8	0.6	3.5
	Total	1.4	0.9	--	4.3	2.2	2.0	2.4	4.7	3.6	7.2	4.6	9.0

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]

(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
42. Beaumont-Port Arthur-Orange													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	1.9	0.1	0.0	0.0	--	--	1.0	0.1	1.9	0.1	3.6	0.1
	FY 73	5.6	0.3	0.0	0.0	0.1	--	3.1	0.2	5.7	0.4	10.5	0.5
	FY 74	5.6	0.6	0.0	0.0	--	0.1	3.0	0.4	5.6	0.8	10.3	0.9
	FY 75	1.9	0.7	0.0	0.0	--	0.1	1.0	0.5	1.9	0.9	3.6	1.1
	Total	15.0	1.7	0.0	0.0	0.1	0.2	8.1	1.2	15.1	2.2	28.0	2.6
43. Charlotte													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.3	0.1	1.2	0.4	--	--	1.0	0.3	1.5	0.5	2.2	0.8
	FY 73	0.8	0.3	3.7	1.5	0.1	--	3.0	1.2	4.6	1.8	6.7	2.7
	FY 74	0.8	0.5	3.7	2.6	--	0.1	2.9	2.1	4.5	3.2	6.6	4.8
	FY 75	0.2	0.5	1.3	3.0	--	0.1	1.0	2.4	1.5	3.6	2.2	5.4
	Total	2.1	1.4	9.9	7.5	0.1	0.2	7.9	6.0	12.1	9.1	17.7	13.7
44. Portland, Maine													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.2	--	0.4	0.1	--	--	0.5	0.1	0.6	0.1	1.0	0.2
	FY 73	0.6	0.2	1.2	0.4	--	--	1.5	0.4	1.8	0.6	3.0	1.0
	FY 74	0.6	0.3	1.2	0.6	--	--	1.5	0.6	1.8	0.9	3.0	1.4
	FY 75	0.2	0.3	0.3	0.7	--	0.1	0.5	0.7	0.5	1.1	1.0	1.6
	Total	1.6	0.8	3.1	1.8	--	0.1	4.0	1.8	4.7	2.7	8.0	4.2
45. Albuquerque													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.1	--	--	--	--	--	0.1	--	0.1	--	0.1	--
	FY 73	0.3	0.1	--	--	0.1	--	0.3	0.1	0.4	0.1	0.4	0.1
	FY 74	0.2	0.2	0.1	--	--	0.1	0.2	0.2	0.3	0.3	0.4	0.4
	FY 75	0.1	0.2	--	--	--	0.1	0.1	0.2	0.1	0.3	0.1	0.4
	Total	0.7	0.5	0.1	--	0.1	0.2	0.7	0.5	0.9	0.7	1.1	0.9
46. Lawrence-Haverhill/ Lowell/Manchester													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.2	--	0.2	0.3	0.1	--	0.5	0.2	0.5	0.3	0.7	0.4
	FY 73	0.4	0.2	0.5	1.2	0.5	0.2	1.3	1.3	1.4	1.6	1.8	2.1
	FY 74	0.4	0.3	0.5	2.0	0.5	0.4	1.3	2.2	1.4	2.7	1.8	3.5
	FY 75	0.1	0.3	0.2	2.3	0.2	0.5	0.5	2.5	0.5	3.1	0.7	4.0
	Total	1.1	0.8	1.4	5.8	1.3	1.1	2.6	6.2	3.8	7.7	5.0	10.0
47. El Paso													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.6	0.2	--	--	--	--	0.3	0.1	0.6	0.2	0.9	0.3
	FY 73	1.9	0.9	--	--	--	--	1.0	0.5	1.9	0.9	2.8	1.1
	FY 74	1.9	1.6	--	--	0.1	0.1	1.0	0.9	2.0	1.7	3.0	2.1
	FY 75	0.6	1.9	--	--	--	0.1	0.3	1.1	0.6	2.0	0.9	2.5
	Total	5.0	4.6	--	--	0.1	0.2	2.6	2.6	5.1	4.8	7.6	6.0

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
48. Las Vegas													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.1	--	--	--	0.1	--	0.1	--	0.2	--	0.3	---
	FY 73	0.4	0.2	0.1	--	0.4	0.2	0.6	0.2	0.9	0.4	1.2	0.4
	FY 74	0.4	0.3	--	--	0.5	0.3	0.6	0.3	0.9	0.6	1.2	0.6
	FY 75	0.1	0.3	--	--	0.1	0.4	0.2	0.4	0.2	0.6	0.3	0.8
	Total	1.0	0.8	0.1	-0.1	1.1	0.9	1.5	0.9	2.2	1.6	3.0	1.8
49. Fargo-Moorhead													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.2	0.1	0.2	-0.1	--	--	0.3	--	0.4	--	0.6	--
	FY 73	0.6	0.2	0.7	-0.2	--	--	0.9	--	1.3	--	1.8	--
	FY 74	0.7	0.4	0.8	-0.4	--	--	1.1	--	1.5	--	2.1	--
	FY 75	0.2	0.5	0.2	-0.5	--	--	0.3	--	0.4	--	0.6	0.1
	Total	1.7	1.2	1.9	-1.2	--	0.1	2.6	0.1	3.6	0.1	5.1	0.1
50. Boise													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.1	--	0.2	--	--	--	0.2	--	0.3	--	0.4	--
	FY 73	0.2	0.1	0.6	--	--	--	0.6	--	0.8	0.1	1.1	0.1
	FY 74	0.2	0.1	0.6	--	--	--	0.6	0.1	0.8	0.1	1.0	0.2
	FY 75	0.1	0.1	0.2	0.1	--	--	0.2	0.1	0.3	0.3	0.4	0.3
	Total	0.6	0.3	1.6	0.1	--	0.1	1.6	0.2	2.2	0.5	2.9	0.6
51. Billings													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.4	--	--	--	--	--	0.2	--	0.4	--	0.8	--
	FY 73	1.0	0.1	--	--	--	--	0.5	0.1	1.0	0.1	1.9	0.1
	FY 74	1.0	0.2	--	--	--	--	0.5	0.1	1.0	0.2	1.9	0.3
	FY 75	0.4	0.2	--	--	--	0.1	0.2	0.2	0.4	0.3	0.8	0.4
	Total	2.8	0.5	--	--	--	0.1	1.5	0.4	2.8	0.6	5.4	0.8
52. Sioux Falls													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.1	--	--	--	--	--	0.1	--	0.1	--	0.1	--
	FY 73	0.2	0.1	0.1	0.1	--	--	0.2	0.2	0.3	0.2	0.4	0.3
	FY 74	0.2	0.1	0.1	0.2	--	--	0.2	0.2	0.3	0.3	0.4	0.4
	FY 75	0.1	0.1	--	0.2	--	0.1	0.1	0.3	0.1	0.4	0.1	0.5
	Total	0.6	0.3	0.2	0.5	--	0.1	0.6	0.7	0.8	0.9	1.0	1.2
53. Cheyenne													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.1	--	--	--	--	--	0.1	--	0.1	--	0.2	--
	FY 73	0.2	0.1	0.2	--	--	--	0.2	0.1	0.4	0.1	0.6	0.3
	FY 74	0.3	0.1	0.1	--	--	--	0.2	0.1	0.4	0.1	0.6	0.3
	FY 75	0.1	0.1	--	--	--	--	0.1	0.1	0.1	0.1	0.2	0.3
	Total	0.7	0.3	0.3	--	--	--	0.6	0.3	1.0	0.3	1.6	0.9

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]

(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
54. Anchorage												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	--	--	--	--	--	--	--	--	--	--	--	--
FY 73	0.1	--	--	--	--	--	--	--	0.1	--	0.2	--
FY 74	0.1	--	--	--	--	--	0.1	--	0.1	--	0.2	--
FY 75	--	--	--	-0.1	--	0.1	--	--	--	--	--	--
Total	0.2	0.1	--	-0.1	--	0.1	0.1	--	0.2	--	0.4	--
55. Burlington												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	--	--	0.1	--	--	--	0.1	--	0.1	--	0.1	--
FY 73	0.1	--	0.4	0.1	--	--	0.3	0.1	0.5	0.1	0.7	0.2
FY 74	--	--	0.5	0.2	--	--	0.3	0.2	0.5	0.2	0.7	0.4
FY 75	--	--	0.2	0.2	--	--	0.1	0.2	0.2	0.3	0.3	0.4
Total	0.1	0.1	1.2	0.5	--	--	0.8	0.5	1.3	0.6	1.8	1.0
56. San Juan												
FY 71	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	--	--	--	1.1	--	--	--	0.1	--	0.1	--	0.1
FY 73	0.1	--	--	0.4	0.1	0.1	0.2	0.4	0.2	0.5	0.2	0.7
FY 74	0.1	--	--	0.6	0.1	0.2	0.2	0.7	0.2	0.8	0.2	1.1
FY 75	--	--	--	0.7	--	0.2	--	0.8	--	1.0	--	1.2
Total	0.2	0.1	--	1.8	0.2	0.5	0.3	2.0	0.4	2.4	0.4	3.1
57. Virgin Islands												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	--	--	--	--	--	--	--	--	--	--	--	--
FY 73	--	--	--	--	--	--	--	--	--	--	--	--
FY 74	--	--	--	--	--	--	--	--	--	--	--	--
FY 75	--	--	--	--	--	--	--	--	--	--	--	--
Total	--	--	--	--	--	--	--	--	--	--	--	--

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
GROUP IV:												
58. Allentown-Bethlehem-Easton												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	3.1	1.7	4.7	3.5	0.5	0.2	6.0	3.8	8.3	5.4	11.3	7.3
FY 74	6.3	5.1	9.5	10.5	1.0	0.4	12.1	11.2	16.8	16.0	22.7	21.8
FY 75	3.1	6.8	4.7	14.0	0.5	0.6	6.0	15.0	8.3	21.4	11.3	29.1
Total	12.5	13.6	18.9	28.0	2.0	1.2	24.1	30.0	33.4	42.8	45.3	58.2
59. Anderson/Muncie												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.3	0.1	1.7	1.1	--	0.0	1.4	0.8	2.0	1.2	2.9	1.8
FY 74	0.7	0.3	3.4	3.3	--	0.1	2.9	2.5	4.1	3.7	5.9	5.4
FY 75	0.3	0.4	1.7	4.3	--	0.1	1.4	3.2	2.0	4.8	2.9	7.0
Total	1.3	0.8	6.8	8.7	--	0.2	5.7	6.5	8.1	9.7	11.7	14.2
60. Bakersfield												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.6	0.2	--	--	--	--	0.4	0.1	0.6	0.2	0.8	0.3
FY 74	1.4	0.5	--	--	--	--	0.9	0.3	1.4	0.5	1.9	0.8
FY 75	0.7	0.7	--	--	--	--	0.5	0.4	0.7	0.7	0.9	1.2
Total	2.7	1.4	--	--	--	--	1.8	0.8	2.7	1.4	3.6	2.3
61. Columbus												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	1.1	0.3	1.1	0.3	0.1	0.1	1.6	0.5	2.3	0.7	3.2	1.0
FY 74	2.1	0.9	2.3	0.9	0.1	0.2	3.1	1.3	4.5	2.0	6.3	2.8
FY 75	1.1	1.2	1.1	1.2	0.1	0.3	1.6	1.8	2.3	2.7	3.2	3.8
Total	4.3	2.4	4.5	2.4	0.3	0.6	6.3	3.6	9.1	5.4	12.7	7.6
62. Davenport-Rock Island-Moline												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	1.4	0.4	2.6	0.3	0.0	0.0	2.7	0.5	4.0	0.7	5.6	1.0
FY 74	2.8	1.2	5.1	0.9	0.1	0.1	5.4	1.5	8.0	2.2	11.3	3.1
FY 75	1.3	1.6	2.6	1.3	0.0	0.1	2.7	2.0	3.9	3.0	5.5	4.2
Total	5.5	3.2	10.3	2.5	0.1	0.2	10.8	4.0	15.9	5.9	22.4	8.3
63. Flint												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.6	0.2	0.1	0.8	0.0	0.1	0.5	0.7	0.7	1.1	1.0	1.6
FY 74	1.2	0.5	0.3	2.6	0.1	0.2	1.0	2.1	1.6	3.3	2.1	4.8
FY 75	0.5	0.7	0.1	3.4	0.1	0.2	0.5	2.8	0.7	4.3	1.0	6.3
Total	2.3	1.4	0.5	6.8	0.2	0.5	2.0	5.6	3.0	8.7	4.1	12.7

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
64. Grand Rapids/Muskegon-Muskegon Hts.													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	1.0	0.3	1.5	4.8	--	0.1	1.8	4.0	2.5	5.2	3.3	6.3
	FY 74	2.0	0.8	3.0	14.3	0.1	0.2	3.6	11.9	5.1	15.3	6.8	15.6
	FY 75	0.9	1.1	1.5	19.1	0.1	0.3	1.8	16.0	2.5	20.5	3.4	24.9
	Total	3.9	2.2	6.0	38.2	0.2	0.6	7.2	31.9	10.1	41.0	13.5	46.8
65. Greensboro													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.6	0.1	0.2	0.2	0.0	0.0	0.6	0.2	0.8	0.3	1.1	0.4
	FY 74	1.2	0.4	0.5	0.5	0.1	0.1	1.2	0.7	1.8	1.0	2.5	1.5
	FY 75	0.7	0.5	0.2	0.7	0.0	0.1	0.6	0.9	0.9	1.3	1.2	1.9
	Total	2.5	1.0	0.9	1.4	0.1	0.2	2.4	1.8	3.5	2.6	4.8	3.8
66. Harrisburg													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	1.6	1.0	4.2	1.0	0.4	0.1	4.3	1.5	6.2	2.1	8.3	3.0
	FY 74	3.2	2.9	8.4	3.0	0.8	0.4	8.6	4.5	12.4	6.3	16.7	9.1
	FY 75	1.6	3.9	4.2	4.0	0.4	0.5	4.3	6.0	6.2	8.4	8.4	12.2
	Total	6.4	7.8	16.8	8.0	1.6	1.0	17.2	12.0	24.8	16.8	33.4	24.3
67. Jacksonville													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.8	0.1	0.0	0.5	0.6	0.2	1.0	0.6	1.4	0.8	1.8	1.0
	FY 74	1.7	0.5	0.1	1.5	1.0	0.8	2.1	2.2	2.8	2.8	3.7	3.5
	FY 75	0.9	0.7	0.0	2.0	0.6	1.0	1.1	2.9	1.5	3.7	1.9	4.6
	Total	3.4	1.3	0.1	4.0	2.2	2.0	4.2	5.7	5.7	7.3	7.4	9.1
68. Knoxville													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	2.8	1.0	2.0	0.7	0.0	0.1	2.8	1.0	4.8	1.8	6.4	2.4
	FY 74	5.7	3.0	3.9	2.0	0.1	0.2	5.7	3.0	9.7	5.2	12.8	6.9
	FY 75	2.9	4.0	2.0	2.6	0.1	0.2	2.8	3.9	4.9	6.8	6.5	9.0
	Total	11.4	8.0	7.9	5.3	0.2	0.5	11.3	7.9	19.4	13.8	25.7	18.3
69. Nashville													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.5	0.1	0.2	-0.1	0.0	0.1	0.5	0.1	0.7	0.1	0.9	0.1
	FY 74	1.0	0.3	0.3	-0.2	0.1	0.2	1.0	0.2	1.4	0.3	1.8	0.4
	FY 75	0.5	0.4	0.2	-0.3	0.1	0.2	0.5	0.2	0.8	0.3	1.1	0.4
	Total	2.0	0.8	0.7	-0.6	0.2	0.5	2.0	0.5	2.9	0.7	3.8	0.9

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
70. Peoria													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	1.3	0.4	2.9	2.7	--	--	3.0	2.3	4.2	3.1	5.8	4.0
	FY 74	2.6	1.2	5.9	8.1	0.1	0.1	6.1	7.0	8.6	9.4	11.8	15.3
	FY 75	1.2	1.6	2.9	10.8	--	0.1	2.9	9.3	4.1	12.5	5.6	16.3
	Total	5.1	3.2	11.7	21.6	0.1	0.2	12.0	18.6	16.9	25.0	23.2	35.6
71. Richmond													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.6	0.2	2.5	0.7	--	0.1	2.3	0.7	3.1	1.0	4.2	1.3
	FY 74	1.2	0.5	5.1	2.0	0.1	0.2	4.7	1.9	6.4	2.7	8.7	3.6
	FY 75	0.6	0.7	2.5	2.7	0.1	0.2	2.3	2.5	3.2	3.6	4.4	4.8
	Total	2.4	1.4	10.1	5.4	0.2	0.5	9.3	5.1	12.7	7.3	17.3	9.7
72. Rochester													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.6	0.1	1.4	1.6	0.8	0.4	1.9	1.5	2.8	2.1	3.8	2.9
	FY 74	1.2	0.4	2.8	4.9	1.6	1.0	3.9	4.4	5.6	6.3	7.7	8.7
	FY 75	0.5	0.6	1.4	6.6	0.8	1.4	1.9	6.0	2.7	8.6	3.7	11.9
	Total	2.3	1.1	5.6	13.1	3.2	2.8	7.7	11.9	11.1	17.0	15.2	23.5
73. Saginaw/Bay City													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	1.1	0.3	2.9	5.0	--	--	2.8	4.0	4.0	5.3	5.5	6.8
	FY 74	2.2	0.8	5.8	15.0	0.1	0.1	5.5	12.1	8.1	15.9	11.0	20.4
	FY 75	1.1	1.1	2.9	20.0	--	0.1	2.8	16.2	4.0	21.2	5.5	27.2
	Total	4.4	2.2	11.6	40.0	0.1	0.2	11.1	32.3	16.1	42.4	22.0	54.4
74. Scranton/Wilkes Barre-Hazilton													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	--	19.9	3.8	0.1	0.1	14.7	2.9	20.1	3.9	27.6	5.4
	FY 74	0.3	0.1	39.8	11.3	0.1	0.2	29.4	8.5	40.2	11.6	55.2	16.0
	FY 75	0.2	0.1	19.9	15.1	--	0.2	14.7	11.2	20.1	15.4	27.6	21.2
	Total	0.6	0.2	79.6	30.2	0.2	0.5	58.8	22.6	80.4	30.9	110.4	42.6
75. Syracuse													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.8	0.3	0.9	0.2	--	--	1.2	0.3	1.7	0.5	2.3	0.7
	FY 74	1.7	0.9	1.8	0.7	0.1	0.1	2.5	1.2	3.6	1.7	5.0	2.4
	FY 75	0.8	1.1	0.9	0.9	0.1	0.2	1.3	1.5	1.8	2.2	2.5	3.1
	Total	3.3	2.3	3.6	1.8	0.2	0.3	5.0	3.0	7.1	4.4	9.8	6.2

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Apn.
76. Tampa													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	2.0	0.6	--	2.7	0.5	0.2	1.8	2.7	2.5	3.5	3.2	4.3
	FY 74	4.1	1.7	0.1	8.0	0.9	0.8	3.6	8.1	5.1	10.5	6.6	12.9
	FY 75	2.0	2.2	0.1	10.6	0.5	1.0	1.8	10.6	2.6	13.8	3.4	16.9
	Total	8.1	4.5	0.2	21.3	1.9	2.0	7.2	21.4	10.2	27.8	13.2	34.1
77. Tulsa													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	1.3	0.4	3.3	0.6	0.1	0.1	2.6	0.7	4.6	1.1	5.9	1.8
	FY 74	2.7	1.3	6.6	1.9	0.1	0.2	5.4	2.0	9.4	3.4	12.0	5.5
	FY 75	1.3	1.6	3.3	2.6	0.1	0.2	2.7	2.6	4.7	4.4	6.0	7.1
	Total	5.3	3.3	13.2	5.1	0.3	0.5	10.8	5.3	18.7	8.9	23.9	14.4
78. Worcester/Fitchburg-Leominster													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.2	0.1	0.4	0.1	0.1	0.1	0.7	0.2	1.0	0.3	1.4	0.4
	FY 74	0.6	0.3	0.6	0.2	0.1	0.2	1.5	0.5	2.1	0.7	2.8	0.9
	FY 75	0.3	0.4	0.4	0.3	0.1	0.2	0.7	0.6	1.0	0.9	1.4	1.2
	Total	1.1	0.8	1.4	0.6	0.3	0.5	2.9	1.3	4.1	1.9	5.6	2.5
79. Youngstown-Warren													
	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	5.9	4.3	2.1	1.3	0.4	0.2	6.0	3.8	8.4	5.8	11.0	14.1
	FY 74	11.9	13.0	4.2	3.8	0.9	0.4	12.1	11.3	17.0	17.2	22.4	22.1
	FY 75	5.9	17.4	2.1	5.0	0.4	0.6	6.0	15.1	8.4	23.0	11.1	29.6
	Total	23.7	34.7	8.4	10.1	1.7	1.2	24.1	30.2	33.8	46.0	44.5	65.8
	FY 71												
	FY 72												
	FY 73												
	FY 74												
	FY 75												
	Total												
	FY 71												
	FY 72												
	FY 73												
	FY 74												
	FY 75												
	Total												

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
GROUP V:												
80. Albany-Schenectady-Troy												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.4	0.1	0.4	0.7	0.3	0.7	0.7	1.1	1.1	1.5	1.4	2.2
FY 74	1.3	0.5	1.2	2.6	0.7	0.4	2.1	2.5	3.2	3.5	4.2	5.1
FY 75	1.7	0.9	1.6	5.2	1.0	0.8	2.9	5.0	4.3	6.9	5.6	10.0
Total	3.4	1.5	3.2	8.5	2.0	1.9	5.7	8.6	8.6	11.9	11.2	17.3
81. Binghamton												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.2	0.1	1.0	0.4	0.1	--	0.8	0.3	1.3	0.5	1.8	0.8
FY 74	0.7	0.4	2.9	1.5	0.4	0.1	2.5	1.3	4.0	2.0	5.6	3.0
FY 75	0.9	0.7	3.8	3.0	0.5	0.4	3.3	2.6	5.2	4.1	7.3	6.2
Total	1.8	1.2	7.7	4.9	1.0	0.5	6.6	4.2	10.5	6.6	14.7	10.0
82. Charleston, South Carolina												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.5	0.1	0.3	0.2	--	--	0.5	0.2	0.8	0.3	1.0	0.4
FY 74	1.4	0.4	1.0	0.8	--	--	1.6	0.8	2.4	1.2	3.1	1.6
FY 75	2.0	1.1	1.3	1.6	0.1	0.1	2.2	1.9	3.4	2.8	4.4	3.8
Total	3.9	1.6	2.6	2.6	0.1	0.1	4.3	2.9	6.6	4.3	8.5	5.8
83. Charleston, West Virginia												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.1	--	0.7	2.0	0.1	--	0.6	1.5	0.9	2.0	1.2	2.7
FY 74	0.4	0.1	2.2	7.9	0.2	0.1	2.0	6.0	2.8	8.1	2.9	10.9
FY 75	0.5	0.2	2.9	15.7	0.3	0.2	2.7	11.8	3.7	16.1	5.1	21.7
Total	1.0	0.3	5.8	25.6	0.6	0.3	5.3	19.3	7.4	26.2	10.2	35.3
84. Des Moines												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.2	0.1	1.1	0.4	--	--	0.9	0.3	1.3	0.5	2.7	0.6
FY 74	0.6	0.3	.34	1.8	0.1	0.1	2.8	1.4	4.1	2.2	5.9	2.7
FY 75	0.9	0.5	4.5	3.6	--	0.1	3.7	2.7	5.4	4.2	7.7	5.2
Total	1.7	0.9	9.0	5.8	0.1	0.2	7.4	4.4	10.8	6.9	15.3	8.5
85. Fresno												
FY 71	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.2	0.1	--	--	--	--	0.1	0.1	0.2	0.1	0.3	0.1
FY 74	0.6	0.4	--	--	--	--	0.4	0.2	0.6	0.4	0.9	0.5
FY 75	0.8	0.7	--	--	--	--	0.6	0.3	0.8	0.7	1.2	1.0
Total	1.6	1.2	--	--	--	--	1.1	0.6	1.6	1.2	2.4	1.6

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS	AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
	Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
86. Fort Wayne												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.2	--	0.7	0.5	--	--	0.4	0.2	0.9	0.5	1.3	0.7
FY 74	0.6	0.3	2.0	2.1	--	--	1.7	1.6	2.6	2.4	3.7	3.5
FY 75	0.8	0.5	2.7	4.2	0.1	0.1	2.4	3.2	3.6	4.8	5.2	7.0
Total	1.6	0.8	5.4	6.8	0.1	0.1	4.5	5.0	7.1	7.7	10.2	11.2
87. Jackson, Mississippi												
FY 71	0.0	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.2	--	--	--	--	--	0.1	0.0	0.2	0.0	0.3	0.0
FY 74	0.5	0.1	--	--	0.1	0.1	0.4	0.1	0.6	0.2	0.8	0.3
FY 75	0.7	0.3	--	--	--	0.1	0.5	0.3	0.7	0.4	0.9	0.5
Total	1.4	0.4	--	--	0.1	0.2	1.0	0.4	1.5	0.6	2.0	0.8
88. Johnstown												
FY 71	0.0	0.0	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.9	0.6	2.2	0.2	--	--	2.2	0.5	3.1	0.8	4.2	1.1
FY 74	2.6	2.3	6.6	0.6	--	--	6.6	2.0	9.2	2.9	12.6	3.9
FY 75	3.4	4.5	8.8	1.2	--	0.1	8.8	3.9	12.2	5.8	16.7	7.9
Total	6.9	7.4	17.6	2.0	--	0.1	17.6	6.4	24.5	9.5	33.5	12.9
89. Lancaster												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.4	0.1	0.9	0.4	--	--	0.7	0.4	1.3	0.5	1.8	0.9
FY 74	1.3	0.5	2.6	1.5	0.1	0.1	2.1	1.6	4.0	2.1	5.4	3.7
FY 75	1.7	1.1	3.3	2.9	--	0.1	2.7	3.1	5.0	4.1	6.8	7.2
Total	3.4	1.7	6.8	4.8	0.1	0.2	5.5	5.1	10.3	6.7	14.0	11.8
90. Mobile												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.4	0.1	0.9	1.0	--	--	0.7	0.9	1.3	1.1	1.5	1.4
FY 74	1.2	0.5	2.8	4.1	0.1	0.1	2.3	3.7	4.1	4.7	4.7	5.8
FY 75	1.6	0.8	3.8	8.2	--	0.2	3.0	7.2	5.4	9.2	6.3	11.4
Total	3.2	1.4	7.5	13.3	0.1	0.3	6.0	11.8	10.8	15.0	12.5	18.6
91. Norfolk-Portsmouth/Newport News-Hampton												
FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 73	0.5	0.1	1.6	0.6	0.3	0.1	1.7	0.5	2.4	0.8	3.4	1.2
FY 74	1.6	0.4	4.7	2.6	0.9	0.6	5.0	2.4	7.2	3.6	10.2	5.4
FY 75	2.1	0.8	6.2	5.1	1.2	1.1	6.6	4.7	9.5	7.0	13.4	10.5
Total	4.2	1.3	12.5	8.3	2.4	1.8	13.3	7.6	19.1	11.4	27.0	17.1

Appendix D (Continued)

1967 Base Year Air Quality Control Costs
Annual and Investment Costs by Metropolitan Area, FY 1971-1975[a]
(million dollars)

METROPOLITAN AREAS		AIR POLLUTION SOURCE CATEGORY						TOTAL AIR QUALITY CONTROL COST					
		Industrial Process		Stationary Combustion		Solid Waste		Lower Limit		Expected		Upper Limit	
		Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.	Inv.	Ann.
92. Raleigh/Durham	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	--	0.7	0.2	--	--	0.5	0.1	0.8	0.2	1.2	0.3
	FY 74	0.2	0.1	2.1	0.7	0.1	0.1	1.6	0.6	2.4	0.9	3.6	1.3
	FY 75	0.3	0.2	2.8	1.4	--	0.1	2.1	1.1	3.1	1.7	4.6	2.5
	Total	0.6	0.3	5.6	2.3	0.1	0.2	4.2	1.8	6.3	2.8	9.4	4.1
93. Reading	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.5	0.2	1.6	0.5	--	--	1.8	0.5	2.1	0.7	2.8	0.9
	FY 74	1.5	0.7	4.8	2.2	--	--	5.5	2.2	6.3	2.9	8.5	3.8
	FY 75	2.0	1.3	6.4	4.3	0.1	0.1	7.5	4.4	8.5	5.7	11.5	7.5
	Total	4.0	2.2	12.8	7.0	0.1	0.1	14.8	7.1	16.9	9.3	22.8	12.2
94. Rockford	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	--	1.1	0.6	--	--	0.8	0.4	1.2	0.6	1.8	0.9
	FY 74	0.3	0.2	3.3	2.4	--	0.1	2.3	1.9	3.6	2.7	5.4	3.9
	FY 75	0.5	0.4	4.4	4.8	--	0.1	3.2	3.7	4.9	5.3	7.4	7.6
	Total	0.9	0.6	8.8	7.8	--	0.2	6.3	6.0	9.7	8.6	14.6	12.4
95. Sacramento	FY 71	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	0.1	--	--	--	--	0.1	0.1	0.1	0.1	0.2	0.1
	FY 74	0.3	0.2	--	--	--	--	0.2	0.1	0.3	0.2	0.4	0.3
	FY 75	0.4	0.4	--	--	--	--	0.3	0.2	0.4	0.4	0.6	0.5
	Total	0.8	0.7	--	--	--	--	0.6	0.4	0.8	0.7	1.2	0.9
96. San Diego	FY 71	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	0.1	--	--	--	--	0.1	0.1	0.1	0.1	0.2	0.1
	FY 74	0.3	0.2	--	--	--	--	0.2	0.1	0.3	0.2	0.5	0.3
	FY 75	0.4	0.4	--	--	--	--	0.3	0.2	0.4	0.4	0.6	0.5
	Total	0.8	0.7	--	--	--	--	0.6	0.4	0.8	0.7	1.3	0.9
97. South Bend	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.5	0.1	1.4	1.2	--	--	1.3	0.9	1.9	1.3	2.7	1.8
	FY 74	1.4	0.6	4.3	4.8	--	--	3.9	3.8	5.7	5.4	8.2	7.3
	FY 75	1.9	1.2	5.7	9.5	0.1	0.1	5.3	7.7	7.7	10.8	11.1	14.7
	Total	3.8	1.9	11.4	15.5	0.1	0.1	10.5	12.4	15.3	17.5	22.0	23.8
98. Utica-Rome	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.1	0.1	0.4	0.1	0.2	--	0.5	0.1	0.7	0.2	0.9	0.3
	FY 74	0.4	0.2	1.2	0.2	0.5	0.2	1.5	0.4	2.1	0.6	2.8	0.8
	FY 75	0.6	0.5	1.6	0.4	0.7	0.4	2.1	0.9	2.9	1.3	3.9	1.8
	Total	1.1	0.8	3.2	0.7	1.4	0.6	4.1	1.4	5.7	2.1	7.6	2.9
99. Wichita	FY 71	0.0	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.6	0.1	--	--	--	--	0.4	0.1	0.6	0.1	1.0	0.2
	FY 74	1.7	0.4	--	--	--	--	1.0	0.3	1.7	0.4	2.8	0.6
	FY 75	2.3	0.7	--	--	0.1	0.1	1.5	0.6	2.4	0.8	4.0	1.2
	Total	4.6	1.2	--	--	0.1	0.1	2.9	1.0	4.7	1.3	7.8	2.0
100. York	FY 71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	FY 73	0.3	0.1	0.5	0.9	0.2	0.1	0.7	0.8	1.0	1.1	1.3	1.6
	FY 74	0.9	0.4	1.6	3.6	0.6	0.2	2.2	3.2	3.1	4.2	4.2	6.0
	FY 75	1.2	0.8	2.2	7.1	0.8	0.5	3.0	6.4	4.2	8.4	5.6	12.1
	Total	2.4	1.3	4.3	11.6	1.6	0.8	5.9	10.4	8.3	13.7	11.1	19.7

[a] The 100 areas are listed by groups in Table C-1 of Appendix C; blanks (--) indicate negligible expenditure required. "Inv." is investment and "Ann." is annual cost.

[b] Also includes New Haven/Waterbury/Meriden SMSA's, although not in originally proposed AQCR.

Appendix E

Solid Waste Disposal
(SIC No. 4953)

Appendix E

Solid Waste Disposal

I. INTRODUCTION

In 1967, the Nation's households, industries, and other commercial activities generated 329 million tons of solid waste--the equivalent of over nine pounds daily for each person. Some of the methods used to dispose of solid waste contribute to the problem of air pollution. Open-burning dumps emit not only significant amounts of particulates but also carbon monoxide and hydrocarbons. Incineration results in the emission of all three pollutants; particulate emissions represent the greatest problem.

In the 100 metropolitan areas, the pattern of solid waste disposal is as follows: 46 percent by open burning; 16 percent by incineration; and the remaining 38 percent by landfill and miscellaneous methods, such as composting or dumping at sea. In 1967, there were an estimated 12,000 land disposal sites (open-burning dumps and landfills) and about 300 municipal incinerator facilities in the Nation. Emissions from open burning and incineration in the 100 areas were estimated at 844 thousand tons of particulates, one million tons of hydrocarbons,[1/] and 1,950 thousand tons of carbon monoxide.

II. CONTROL OF EMISSIONS

About 75 percent of the land disposal sites in the 100 areas practice open burning and about 90 percent of the incinerators do not meet the requirements of the New York State Incinerator Standard, which was the particulate regulation selected for this analysis. None of these incinerators, however, is thought to exceed the standard of 1.46 pounds of sulfur dioxide per million Btu input, which is the sulfur oxides regulation applied in this report to incinerators (see Appendix A).

[1/] Measured as methane.

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Estimates were made of the costs of reducing emissions from solid waste disposal facilities through elimination of open-burning dumps in favor of incineration and sanitary landfill and the installation of particulate control equipment on all municipal incinerators.

III. EMISSION CONTROL COSTS

A. Methodology

Air pollution control costs for solid waste were obtained by:

1) Determining the quantity and method of disposal of collected refuse.

   The total collected refuse generated in any metropolitan area was computed on the basis of 5.3 pounds per capita per day [Ref. 1]. Specific data for a metropolitan area were used when available. The amount of refuse incinerated was obtained from incinerator listings obtained from previous studies [Ref. 2]. All incinerators were assumed to be operating at their stated capacity, and the balance of the refuse which was not incinerated was assumed to be disposed of by other methods: landfill, burning dumps, ocean dumping, composting, etc. When no detailed information on the method of disposal existed, it was assumed that 75 percent of this remaining amount was open burned [Ref. 1].

2) Determining the quantity and method of disposal of uncollected refuse.

   Uncollected refuse was estimated using a rate of 4.7 pounds per capita per day [Ref. 1]. This refuse was assumed to be presently disposed of by 50 percent landfill, 25 percent open burning, and 25 percent domestic and commercial incineration.

3) Determining incinerator control costs.

   All existing municipal incinerators must be upgraded to some extent to comply with regulations. The cost for this upgrading is presented in Table E-1.

Table E-1

COST OF UPGRADING MUNICIPAL INCINERATORS

Year of Construction	Cost of Upgrading ($ per daily ton of capacity)	
	Investment	Annual
Before 1961	500	360
1961-1964	400	330
1965-1967	200	310

4) Determining opening burning control costs for collected refuse.

All present open burning must be discontinued. It was assumed that 25 percent of this amount would go to new incinerators at a cost of $5,600 per daily ton for furnaces in the 300 ton per day or larger size, and $7,500 per daily ton for furnaces smaller than 300 tons per day [Refs. 3, 4, 5]. The annualized cost of operating an incinerator was based on $6 per daily ton and 300 days per year. The remaining 75 percent of open burning would go to sanitary landfills at an additional cost of $0.30 per ton.[1/] No initial investment costs were included since land and personnel for the burning dump were already on hand. In metropolitan areas where there are no municipal incinerators, all open burning would be converted to sanitary landfill; that is, no new incinerators will be built in these areas.

5) Determining control costs for uncollected refuse.

Uncollected refuse control costs were based on all current open burning (25 percent of all solid waste) going to sanitary landfill at a cost of $0.40 per ton, and existing incineration (also 25 percent of the total) requiring upgrading at an investment cost of $1000 per daily ton of capacity with an annualized cost of $259 per daily ton. Twenty percent of existing small

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[1/] This is the only cost above that required to operate a burning dump. (See Reference 3.)

incinerators were assumed to presently meet the New York State regulation, and 20 percent were assumed to convert to landfill at no additional cost.

6) Determining additional costs incurred by 1975.

These costs were based on the 1967 disposal practices, but were varied to accommodate population changes as well as a 3 percent yearly increase in the amount of solid waste generated per capita. These increases were then treated in the same manner as the 1967 values to arrive at a control cost.

7) Assuming that all California metropolitan areas were controlled through local efforts and any costs incurred were not due to Federal action.

The following examples of computing a typical metropolitan area cost for controlling emissions from solid waste disposal (collected and uncollected refuse) were based on metropolitan area data presented in Table E-2 below.

Table E-2

EXAMPLE METROPOLITAN AREA SOLID WASTE DATA

Year	Population (1000)	Refuse Quantities (tons/day)			
		Generated	Collected	Incinerated	Open Burned
1967	1536	7680	4060	1325	2050

The following example represents metropolitan area cost calculations for collected refuse:

1) Cost to control incineration (all pre-1961):

1967 investment: 1325 tons/day x $500/ton = $662,500

annual: 1325 tons/day x $360/ton/year = $477,000

2) Cost to control open burning:

Convert 3/4 to landfill; 3/4 x $0.30/ton x 360 days/year x 2050 tons/day = $166,000/yr.

Convert 1/4 to new incinerators; 1/4 x 2050 x $5600/ton = $47,870,000.

Annualized cost for incinerators @ $1800/ton ($6/daily ton) 1/4 x 2050 x $1800/ton = $925,000/year.

A metropolitan area cost for uncollected refuse is as follows:

Uncollected = Generated - Collected = 4.7 lbs/capita/day.

1) To convert open burning to landfill:

1/4 x (7680 - 4060) tons/day x $0.40/ton x 360 days/year = $130,000/yr.

2) Capital and annualized cost to upgrade small incinerators:

1/4 x (7680 - 4060) x .60 x $259/daily ton = $142,000/year:

1/4 x (7680 - 4060) x .60 x $1000/daily ton = $544,000.

The resulting 1967 costs are presented in Table E-3.

Table E-3

SUMMARY OF 1967 EXAMPLE METROPOLITAN AREA COSTS

Waste Disposal Practice	Investment ($1000)	Annualized ($1000)
Municipal Incinerators	662.5	477
Collected Open Burning to Landfill	-	166
Collected Open Burning to Incinerator	2879.0	925
Uncollected Open Burning to Landfill	-	131
Uncollected Open Burning to Incinerator	544.0	142
Totals	4076.5	1841

A similar procedure was carried out for each year from 1967 through 1975 to determine the costs of controlling the emissions from the incremental solid waste generated annually.

This example provides some insight into those factors which substantially affect the final costs. The major single factor is the cost for new incinerators required to control 25 percent of the existing open burning. The high initial costs and the high yearly costs accounted for about 50 percent of the total annual costs for this metropolitan area.

The installation of electrostatic precipitators (ESP's) in place of scrubbers on existing municipal incinerators was also investigated. Annualized costs for ESP's are about 50 percent of scrubber costs. However since no ESP's are currently used for controlling particulate emissions from incinerators, they were not considered in this analysis. Assuming some of the larger incinerators were to go to ESP's as a means of control, a typical metropolitan areas annualized cost would be reduced by about 10 percent.

Cost estimates for disposing of junked automobiles in controlled incinerators were based on an assumption that 50 percent of these automobiles were not being open burned. Based on data presented in Section III.B., costs of controlling particulates from auto body incinerators would only add about 1 to 3 percent to the metropolitan area investment cost and even less to the annualized cost. Therefore, separate estimates of the cost of controlling junked auto disposal were not made because the percent contribution of these costs was less than the expected error of the major cost estimates.

Accuracy of the cost estimates made for solid waste disposal emission controls cannot be well established. Since the distribution of solid waste disposal methods is not as well known as the specific control costs for the hardware, etc., a change in the basic assumptions regarding the present and planned solid waste disposal methods could drastically affect estimates of control costs. Assuming that the basic assumptions are correct and charging the entire cost of those new incinerators required to control part of the open burning to air pollution control, it is believed that these costs are accurate within ± 30 percent. Annualized costs are believed accurate to within ± 25 percent.

B. Control Costs

The following air pollution control costs were utilized in estimating metropolitan area solid waste disposal expenditures.

1. Municipal Incinerator Control Costs

Table E-4 presents the cost of controlling municipal incinerators with wet scrubbers.

Table E-4

MUNICIPAL INCINERATOR CONTROL COSTS

Size (tons/day)	Flue Gas Volume (1000 acfm)[a]	Collection Eff. (percent)	Installed Cost		Annualized Cost	
			($1000 total)[b]	($/daily ton)	($1000)	($/daily ton)
50	40	85	28	560	20	400
100	80	85	52	520	39	390
200	160	85	100	500	77	380
300	240	85	150	500	115	380
500	350	90	250	500	172	340
600	420	90	300	500	207	340
700	420	95	350	500	213	300
1000	600	95	480	480	302	300

[a] For sizes 50 - 300 tons per day, use 800 acfm/ton.
For sizes 500 - 600 tons per day, use 700 acfm/ton.
For sizes 700 - and larger, use 600 acfm/ton

[b] See Figure E-1.

Since installed costs did not vary by more than about 10 percent, an average cost of $500 per daily ton was used. For incinerators built between 1961 and 1964, 80 percent of the control costs were used. For units built after 1965, a control cost of $200 per daily ton was arbitrarily used since these units were assumed to have some type of acceptable control device already in place.

Annualized costs were based on a 13.3 percent capital charge and on the following operating cost equation [Ref. 6]:

$$G = S\ [0.7457HK\ (Z + \frac{Qh}{1980}) + WHL + M] = 0.3985$$

where: S = acfm;
H = 7200 hours/year;
K = $.01/kwh
Z = 0.006 HP/acfm;
W = 0.005 gal/hr-acfm;
h = 30 feet;
$L = \$0.5 \times 10^{-3}$/gal-hr.

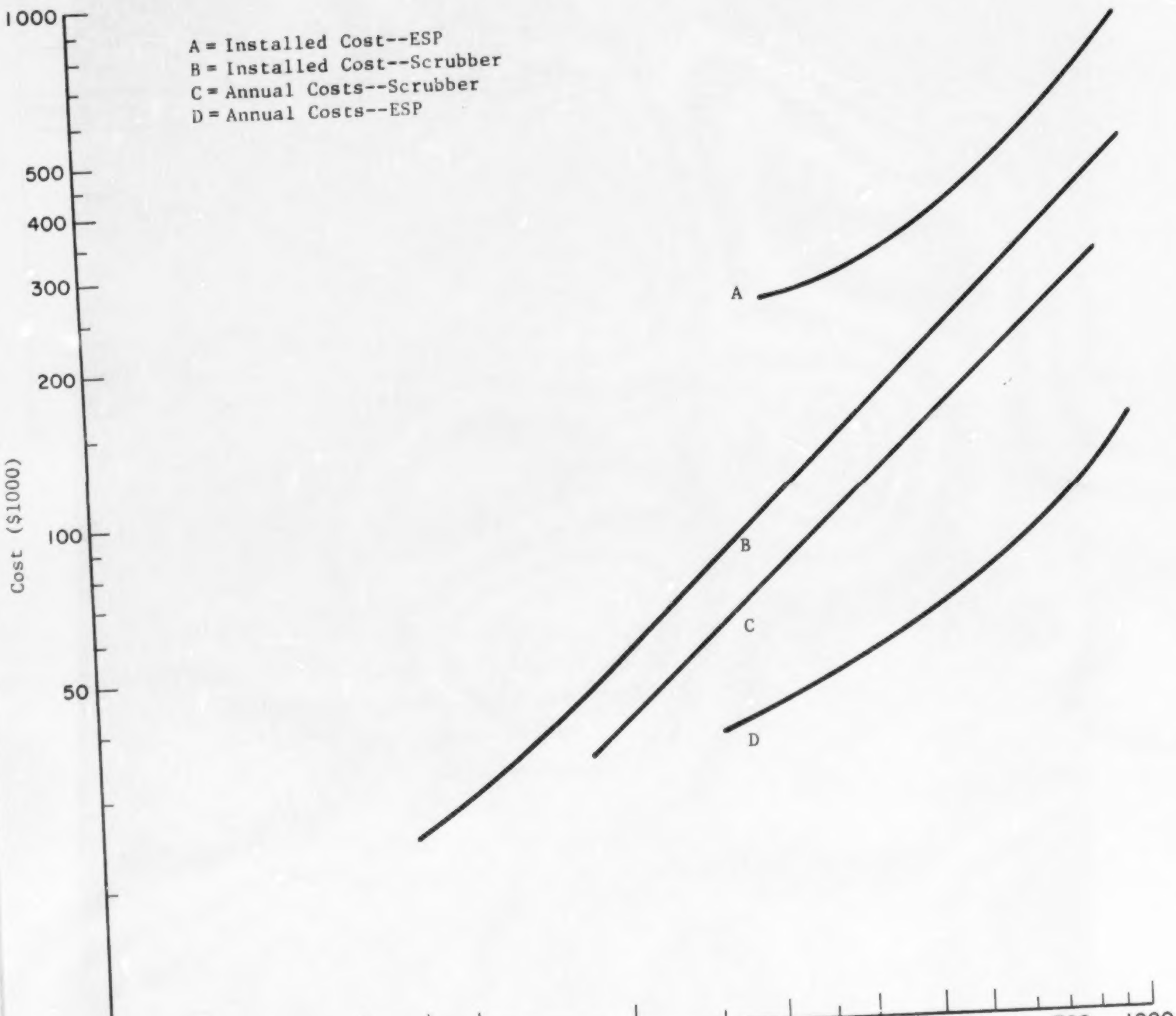

Fig. E-1. Municipal Incinerator Particulate Control Costs.

Operating costs for a wide range of incinerator size were calculated and an average cost based on dollars per ton used for cost estimating purposes.

2. Control Costs for Smaller-Sized Incinerators

A one ton per day model size unit operating for 5 hours per day and 360 days per year (1800 hours per year) was used as a base for calculating control cost. Installed cost of a scrubber for this size unit (400 pounds per hour capacity) designed to meet the New York State regulation is about $1000.[3] Particulate control efficiencies on the order of 60 to 80 percent are required.

Annualized control costs were calculated as follows [Ref. 7]:

$$G = S[0.7457HK\ Z + \frac{Qh}{1980} + WHL + M] = 920\ (0.119)$$

$$= \$109/\text{year/daily ton}$$

where:

$S = 920$ acfm[4];
$H = 1800$ hours/year;
$K = \$0.01$/kwh;
$Z = 0.006$ hp/acfm;
$Q = 0.01$ gals/acfm;
$h = 30$ feet;
$W = 0.005$ gal/hr-acfm;
$L = \$0.05 \times 10^{-3}$/gal-hr;
$M = \$0.03$/acfm.

Capital charges at 15%, (.15 x $1000) = $150/year/daily ton
TOTAL Annualized Cost = $259/daily ton

3. Auto Body Disposal Costs

Calculations to determine investment and annual costs of auto body disposal for a metropolitan area are presented below. A controlled incinerator handling 30 cars per day costs about $25,000 [Ref. 10].

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[3] An average value; control costs for small incinerators vary from $1300 to $600 per daily ton of refuse burned [Ref. 8].

[4] Based on 16,000 ft^3 of flue gas per 10^6 Btu of heat input, and 5000 Btu/lb of refuse.

$$5000\ \frac{\text{Btu}}{\text{lb.}} \times 4000\ \text{lb/hr} \times \frac{1}{60\ \text{min/hr}} \times \frac{16{,}000\ \text{ft}^3}{10^6\ \text{Btu}} = 535\ \text{ft}^3/\text{min at } 70°\text{F},$$

or about 920 acfm at 450°F.

a) Investment Cost:

$$\text{Investment Cost/Car} = \frac{\$25{,}000}{30 \text{ cars/day} \times 300 \text{ days/year}} = \$2.8\text{/car/year.}$$

$$\text{Metropolitan Area Investment Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27 \text{ cars}}{1 \text{ year}}$$

$\times\ 0.50$[5] $\times\ \$2.8\text{/car/year} = \$39\text{/1000 population.}$

b) Operating Cost, assuming $4/car:

$$\text{Metropolitan Area Operating Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27 \text{ cars/1000 population}}{1 \text{ year}}$$

$\times\ 0.50$[5] $\times\ \$4\text{/car} = \$56\text{/1000 population/year.}$

C. Estimated Costs

The resulting costs were totaled for the 100 metropolitan areas; these are shown in Table E-5. Annual control costs would average approximately $1.18 per ton of solid waste when the plan is fully implemented. The emissions of particulates, hydrocarbons, and carbon monoxide would be reduced from 844, 160 and 1950 thousand tons, respectively, in 1967 to 167, 43, and 262 thousand tons, respectively, by 1975.

IV. CONTROL COSTS RESULTING FROM GROWTH

The amount of solid waste generated is expected to grow in proportion to the population of each area. In addition, a three percent per year increase in the per capita production for solid wastes was assumed. The projected growth costs were based on the expected ultimate control levels of 91.0, 95.0, and 90.0 percent for particulates, hydrocarbons and carbon monoxide, respectively. The calculations consisted of multiplying the 1967 total investment and annual costs for controlling the base production by the population growth factor including the increase in per capita production to obtain annual investment and annual costs to control the growth in production. The results of the cost analysis of controlling additional solid waste loads are shown in Table E-6 along with the expected emissions resulting, assuming that control is at the ultimate levels for each pollutant.

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[5] Assuming 50 percent of all scrapped cars are presently being burned.

Table E-5

SOLID WASTE DISPOSAL

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	844	--	160	1950	53.5	--	63.0	63.0						
FY71	809	--	160	1950	55.5	--	63.0	63.0	6.9	9.9	12.9	3.6	4.8	6.0
FY72	646	--	142	1520	64.5	--	69.0	67.0	31.5	45.0	58.5	20.0	26.7	33.4
FY73	389	--	108	1200	78.6	--	78.0	75.0	46.7	66.7	86.7	44.6	59.5	74.4
FY74	220	--	61	525	88.0	--	90.0	86.0	27.6	39.4	51.2	59.3	79.1	98.9
FY75	167	--	43	262	91.0	--	95.0	90.0	7.3	10.4	13.5	63.4	84.5	106.0
Total -									120.0	171.4	222.8	190.9	254.6	318.7

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table E-6

SOLID WASTE DISPOSAL

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY	ADDITIONAL PRODUCTION (thousand tons/year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	N.A.	17	8	--	2	16	5.3	7.5	9.7	2.5	3.4	4.3
FY72	N.A.	22	10	--	3	21	7.7	11.0	14.3	6.3	8.4	10.4
FY73	N.A.	27	13	--	4	26	9.1	13.0	17.0	10.7	14.4	17.8
FY74	N.A.	34	16	--	5	31	7.2	10.4	13.5	14.3	19.0	23.7
FY75	N.A.	40	19	--	6	37	5.3	7.5	9.7	16.8	22.5	27.9
Totals -							34.6	49.4	64.2	50.6	67.7	84.1

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B. N. A. indicates not applicable.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix F

Steam-Electric Power Plants
(SIC No. 4911)

Appendix F

Steam-Electric Power Plants

I. INTRODUCTION

Steam-electric power plants consume 21 percent of the Nation's fuel, including 64 percent of the coal; as a result, they produce tremendous quantities of air pollutants. Nationally, power plants contribute about 20 percent of the particulates, although particulate emissions from them are approximately 80 percent controlled, and 49 percent of the sulfur oxides, which are essentially uncontrolled.

In 1967, about 252 of the national total of 410 power plants[1] were located in the 100 metropolitan areas; these plants generated 420 billion kilowatt hours of electricity. This study did not include power plants of the Tennessee Valley Authority.

II. CONTROL OF EMISSIONS

Present control practice for particulates, a problem only with coal burning,[2] is to use electrostatic precipitators sometimes along with high efficiency mechanical collectors. The present level of industry control of these emissions is estimated at about 80 percent. Reduction of sulfur oxide emissions has been accomplished only in a few locations and generally by substituting low-sulfur content fuel for high-sulfur fuel of the same type or by switching to another fuel type. Nationally in 1967, the burning of fossil fuels accounted for 15.0 million tons of sulfur oxides and over 5.5 million tons of particulates. Within the 100 metropolitan areas, 1967 emissions amounted to over 6.8 million tons of sulfur oxides and approximately 2.2 million tons of particulates.

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[1] Steam-electric power plants with capacities of 25 megawatts and greater that burn coal and/or fuel oil.

[2] Oil and gas fired plants, uncontrolled, meet the requirements of the particulate emission standard assumed in this analysis.

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III. DISCUSSION AND EVALUATION OF ENGINEERING DATA IN COST ESTIMATION

The basic engineering data information required to estimate control costs for the power generating industry consisted of: (a) an evaluation of the various combustion processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required emission levels.

Uncontrolled emission rates for SO_2 and particulates for the various fuels are tabulated in Table F-1.

Table F-1

PARTICULATE AND SO_2 UNCONTROLLED EMISSION FACTORS

Fuel	Particulate Emission Factor ($lb/10^6$ Btu input)	SO_2 Emission Factor ($lb/10^6$Btu input)
Coal		
Pulverized firing	$0.69A^a$	$1.46S^b$
Cyclone firing	0.08A	$1.46S^b$
Oil	0.069	1.06S
Gas	0.015	Negligible

[a] 0.69 multiplied by the percent ash content, A.

[b] 1.46 multiplied by the percent sulfur content, S.

At present, the average level of particulate control is estimated at 80 percent. Control of SO_2 in the flue gas is practiced only at a few experimental sites. Sulfur dioxide control is being approached on the basis of fuel substitution, either by switching fuels or by changing to a lower sulfur content fuel of the same type.

On the basis of the State of Maryland Particulate Standard for Fuel Burning Installations, removal requirements were calculated as a function of input heat rate. These are shown for coal in Table F-2.

Particulate emissions from all boilers using oil and gas are acceptable at all firing rates.

Table F-2

PARTICULATE REMOVAL EFFICIENCIES REQUIRED

Input (10^6Btu/hr)	Percent Efficiency Required	
	Cyclone Boiler	Pulverized Boiler
100	50.0	93.0
500	62.5	95.5
1000	67.5	96.0
5000	75.0	96.8
10000	77.5	97.2

For the purpose of this study, acceptable SO_2 emission (Btu basis) were equal to those that would result from the use of 1 percent sulfur content coal. The equivalent sulfur percentage in fuel oil which would satisfy this standard was calculated to be 1.38 percent based upon an average residual oil Btu value of 145 thousand Btu per gallon. Of course, any type of natural gas would result in acceptable levels of SO_2 emissions.

This study considered several SO_2 control alternatives. Of these, the wet dolomite process seemed to be promising; however, recent reports [Ref. 3] indicated that selection of this system would be premature at this time. Therefore, it was decided that fuel switching was the most reliable alternative available. Based on available data indicating the feasibility of fuel oil desulfurization [Refs. 4, 5], a switch to fuel oil desulfurnizated to 1.14 percent sulfur[3/] was selected to control SO_2 and particulates. Selection of this alternative herein should not be

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[3/] Cost data were available for this oil.

construed as a recommendation. It was chosen basically for two reasons: first, it can satisfy the SO_2 control levels required for this study and second, simplified calculations have shown that the adoption of this alternative would lead to control costs consistent with other alternatives available for the simultaneous control of both particulates and SO_2.[4]

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Data on steam-electric power plants of 25 megawatts and greater in capacity and data about their fuels were compiled from Federal Power Commission reports [Refs. 6,7]. The basic data included annual consumption of coal and oil by plant. Plant capacity and location were also known.

Estimated cost of controlling emissions from steam-electric plants was approximated by using the costs of changing from high-sulfur content coal or oil to desulfurized fuel oil. If a plant, according to the FPC survey, was burning coal with greater than 1 percent sulfur, or oil with greater than 1.38 percent, then it was assumed to require low-sulfur content fuel oil.

When a switch to desulfurized residual oil was indicated, annual operating costs of control were based on the cost differential between Btu equivalents of coal and oil at local metropolitan prices, plus a premium of $0.40 per barrel of oil for desulfurization to 1.14 percent. If the switch was from coal to oil, it was necessary to estimate boiler-burner conversion costs. Data supplied by private sources[5] were used to develop a conversion cost per unit of capacity. An investment cost of $2864 per megawatt of capacity was used. If a plant was reported to have used fuel oil or coal and fuel oil in 1967, conversion costs were not assigned because it was assumed that all boilers were capable of burning oil. Plant costs were totalled for the 100 metropolitan areas.

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[4] At a premium of 40¢ per barrel; this is equivalent to about $1.50 per ton of coal equivalent which is in the range of costs indicated for several alternatives presented in the NESS study.

[5] Gunnar Taska of Cleaver-Brooks, Minneapolis, Minnesota.

B. Estimated Control Costs

The resulting costs, which exclude plants already using low-sulfur fuel, were totalled for the 100 metropolitan areas; these are shown in Table F-3. Total investment costs amount to $161.3 million with an ultimate annual cost of $631.0 million by FY 1975. Overall emission control levels of 98.7 and 63.6 percent for particulates and sulfur oxides, respectively, would be achieved as a result of the control alternative chosen. These would result in ultimate emissions of 198 thousand tons and 2.5 million tons for particulates and sulfur oxides, respectively, in contrast to the 2.19 million and 6.86 million tons in 1967.

V. CONTROL COSTS RESULTING FROM GROWTH

This study assumed that there would be net increases in the number of fossil-fuel burning power generating plants during the period of implementation in the 100 metropolitan areas. For the purposes of cost analysis, it was further assumed that these plants would be designed to burn residual fuel oil and hence no added investment would be required. Annual costs were based on the price differential in fuel costs, assuming the 1967 fuel mix for the new plants.

In the 100 metropolitan areas an average annual growth rate in generating capacity of 3 percent per year was assumed. This is much less than the expected national growth; however, there are noticeable trends to locate steam-electric power plants in lightly populated locations. The cost analysis, as shown in Table F-4, indicates that annual costs of $155.2 million would be required to control the added capacity put into service within the 100 areas by 1975. Without the additional controls imposed by the standards, emissions of particulates and sulfur oxides from both the 1967 base and additional growth would amount to 2.55 million tons and 8.52 million tons by 1975; with the act in effect, the emissions would be reduced to 231 thousand tons and 3.12 million tons.

Table F-3

STEAM-ELECTRIC POWER PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	2190	6860	--	--	86.0	0.0	--	--						
FY71	2050	6577	--	--	86.8	4.1	--	--	5.4	6.7	8.0	32.8	41.0	49.2
FY72	1500	5361	--	--	90.4	21.9	--	--	31.8	39.7	47.6	174.0	217.0	260.0
FY73	719	3640	--	--	95.4	47.0	--	--	51.9	64.9	77.9	371.0	466.0	559.0
FY74	292	2707	--	--	98.1	60.6	--	--	31.4	39.2	47.0	481.0	601.0	721.0
FY75	198	2500	--	--	98.7	63.6	--	--	8.6	10.8	13.0	505.0	631.0	757.0
Total -									129.1	161.3	193.5	1563.8	1956.0	2346.2

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table F-4

STEAM-ELECTRIC POWER PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (number of sources)	ADDITIONAL PRODUCTION	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS[c] (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	27	N.A.	14	273	--	--	--	--	--	20.0	25.0	29.9
FY72	36	N.A.	19	356	--	--	--	--	--	47.7	59.6	71.5
FY73	45	N.A.	23	442	--	--	--	--	--	79.5	99.4	119.3
FY74	53	N.A.	28	530	--	--	--	--	--	104.9	131.1	157.3
FY75	62	N.A.	33	621	--	--	--	--	--	124.2	155.2	186.3
Totals							--	--	--	376.3	470.3	564.3

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B; N.A. indicates not applicable.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

[c] It is assumed that the plants will be designed to burn residual fuel oil; hence, no added investment will be required. Annual costs are based on a price difference in fuel costs.

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Appendix G

Industrial Boilers

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Appendix G

Industrial Boilers

I. INTRODUCTION

In the United States and 100 metropolitan areas in 1967, there were an estimated 307 thousand and 219 thousand industrial boilers, respectively, that supplied steam for material processing, space heating, and, in some large industrial complexes, electric-power. Though the boilers involved were generally smaller than those in steam-electric power plants, they caused a significant amount of pollution in highly industrialized areas. Overall, they accounted for 32 percent of particulates and 24 percent of sulfur oxides emitted from stationary combustion sources in the 100 metropolitan areas.

In 1967, boilers in industrial plants in the 100 areas emitted 1.5 million tons of particulates and about 4.0 million tons of sulfur oxides compared to the U.S. emissions of 3.0 million tons for particulates and 5.3 million tons for sulfur oxides. Average control at that time was estimated at 62 percent for particulates; little, if any, control of sulfur oxide emissions was in effect.

II. CONTROL OF EMISSIONS

The Federal particulate emission control regulation for fuel combustion sources can be met by using various types of gas-cleaning equipment. However, such control devices have little effect on sulfur oxides. As mentioned in Appendix F, techniques for removing sulfur from gas streams have not been fully developed; therefore, this report assumes the change from high-sulfur content coal or oil to a low-sulfur content oil. Such a change in fuel will reduce both particulates and sulfur oxides to comply with the applicable regulations.

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III. DISCUSSION AND EVALUATION OF TECHNICAL DATA USED IN COST ESTIMATION

The procedure used for estimating the cost of air pollution control for industrial boilers was as follows:

a) Relevant data on the industry [Ref. 1] were projected to 1967.

b) Particulate and SO_2 emissions were calculated by region.

c) Emissions for the average plant in each region were evaluated for compliance with emission standards, and control methods determined.

d) Cost of control was estimated.

Baseline data on fuel consumption for heat and power production by manufacturing firms [Ref. 1] were tabulated for each region by 2-digit SIC code along with the number of firms in each classification. Consumption was then estimated for 1967 by expanding the 1963 figure by the Federal Reserve Board index of production [Ref. 2] for each manufacturing class, assuming that national growth had been evenly distributed to all regions.

Particulate and SO_2 emissions for 1967 were calculated from the estimated consumption of coal and oil, aggregated for each region.

Fuel consumption for 1963 divided by the number of firms in each SIC category gave the average consumption per plant for that year. On the assumption that growth had occured in the number of plants rather than in the scale of operation, the average 1963 plant size for each SIC category in each region was divided into the corresponding 1967 fuel consumption estimates to determine the 1967 number of plants. Consumption of coal in the 100 areas was estimated to be 36,759,000 tons in 1967, equal to 37 percent of the estimated U.S. industrial consumption of 99,205,000 tons. Consumption of oil was estimated to be 136,738,000 barrels in 1967, equal to 75 percent of the estimated U.S. industrial consumption of 181,293,000 barrels [Ref. 3].

To determine the particulate and SO_2 emission rates per plant, it was assumed that boilers were operated continuously throughout the year. The analysis showed that in all cases uncontrolled particulate emissions from coal consumption exceeded the specified standard at all levels of operation in all regions.

Particulate emission factors are presented in Table G-1. An overall level of particulate control of 62 percent was assumed; 1967 emissions were calculated on this basis.

Table G-1

PARTICULATE EMISSION FACTORS FOR INDUSTRIAL BOILERS

Annual Btu Input	Fuel Type	
	Coal (lb/ton coal)	Oil (lb/1000 gal)
$< 87 \times 10^9$	5A[a]	19
$> 87 \times 10^9$	13A[a]	19

[a] Ash content expressed as a percent.

Emission factors for SO_2 are presented in Table G-2. The sulfur content of residual oils in the Eastern Region (Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, West Virginia, and Kentucky) averaged 1.26 percent and this resulted in emissions within the specified standard. In all other areas, combustion of residual oils, on the average, produced emissions of SO_2 in excess of the assumed standard.

Table G-2

SO_2 EMISSION FACTORS FOR INDUSTRIAL BOILERS

Fuel Type	Emission Factor
Coal	38S[a] (pounds/ton coal)
Oil	157S[a] (pounds/1000 gal oil)
Gas	0.4 (pounds/10^6 c.f. gas)

[a] Sulfur content expressed as a percent

IV. COST ESTIMATION

Estimates of control costs were made by assuming that all uncontrolled coal combustion was replaced by low-sulfur oil-fired units and that uncontrolled oil-fired units were switched to low-sulfur content oil. The resultant cost differentials were based on coal and oil price survey data [Ref. 4] interpolated geographically for regions not included in the survey. Cost of conversion from coal to oil was calculated on the basis of an investment cost of $16,500 resulting in annual depreciation and capital charges of $3,300 per unit converted. The estimated cost of controlling emissions from the 1967 sources are shown in Table G-3.

V. CONTROL COSTS RESULTING FROM GROWTH

Fuel consumption for 1967 was estimated by projecting 1963 industrial census data using the Federal Reserve Board index of production for each industrial classification. This technique was also used to project the number of industrial boilers through Fiscal Year 1975. It was assumed, for the purpose of estimating costs, that growth would be through increases in the number of boilers; that is, the average size of boilers was assumed not to increase.

Costs attributable to growth in the number of industrial boilers are given in Table G-4. Projected costs consist only of additional fuel costs; no conversion costs are involved. By 1975, without the act in effect, emissions in the 100 areas from both 1967 base sources and growth-related sources would reach 1930 thousand tons of particulates and 4780 thousand tons of SO_2; with the act in effect, emissions would be reduced to 72 thousand tons and 1759 thousand tons, respectively.

Table G-3

INDUSTRIAL BOILERS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	1540	3970	--	--	62.0	0.0	--	--						
FY71	1454	3820	--	--	71.3	3.6	--	--	14.3	22.0	33.0	12.3	19.0	28.5
FY72	1108	3240	--	--	78.1	18.2	--	--	59.7	91.9	138.0	61.8	95.0	142.0
FY73	595	2380	--	--	88.3	40.0	--	--	96.9	149.0	224.0	135.0	208.0	312.0
FY74	223	1750	--	--	93.6	55.7	--	--	77.4	119.0	178.0	189.0	290.0	435.0
FY75	50	1460	--	--	98.8	63.0	--	--	35.2	54.2	81.3	213.0	328.0	492.0
Total -									283.5	436.1	654.3	611.1	940.0	1409.5

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table G-4

INDUSTRIAL BOILERS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY	ADDITIONAL PRODUCTION (number of sources)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	25,300	N.A.	6	140	--	--	10.8	16.6	24.9	7.8	12.0	18.0
FY72	32,600	N.A.	7	179	--	--	14.6	22.5	33.8	17.7	27.2	40.8
FY73	39,800	N.A.	9	219	--	--	17.9	27.5	41.3	30.7	47.3	71.0
FY74	47,100	N.A.	11	259	--	--	16.2	24.9	37.4	46.0	70.8	106.0
FY75	54,300	N.A.	12	299	--	--	12.6	19.4	29.1	54.5	83.8	126.0
Totals -							72.1	110.9	166.5	156.7	241.1	361.8

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B; N.A. indicates not applicable.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix H

Commercial-Institutional Heating Plants

Appendix H

Commercial-Institutional Heating Plants

I. INTRODUCTION

Within the 100 metropolitan areas in 1967, there were approximately 607 thousand heating plants that provided heat and steam for hotels, retail stores, schools, hospitals, and other such establishments. In 1967 in the 100 metropolitan areas, an estimated 3 million tons of coal, 170 million barrels of oil, and one trillion cubic feet of gas were consumed in these heating plants. More than 64 thousand tons of particulates and 675 thousand tons of sulfur oxides were emitted compared to the national emissions of 105 thousand tons and 1110 thousand tons, respectively.

II. CONTROL OF EMISSIONS

Currently, little or no control is being used for heating plants. However, the emissions from commercial and institutional establishments can be reduced readily by changing to fuels with low ash and sulfur contents, namely, natural gas and oil. Thus, by FY 1975, particulate and sulfur oxide emissions can be reduced by 51.5 and 14.0 percent, respectively. The pattern of use for fuel oil and natural gas among commercial and institutional establishments varies by area; the 1967 pattern of consumption of medium grade oil (No. 4) and natural gas was used as the basis for calculating costs.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

In order to estimate the cost of controlling air pollution caused by commercial and institutional space heating, it was necessary to (a) determine the amount of coal, oil, and gas consumed by this group of users in each metropolitan area; (b) determine the extent of uncontrolled emissions and the control

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methods appropriate for achieving the required degree of control; and (c) determine the investment and operating cost differentials per unit resulting from compliance.

On the basis of fuel balance data for 24 regions [Ref. 1], it was found that the amount of energy consumed in heating commercial and institutional buildings correlated closely ($r = 0.86$) with population. This relationship is expressed by the following equation:

$$\log H = 14.96941 + 1.17502 \log P;$$

where: H = energy required in 10^9 Btu per degree day and
P = the area population.

The estimated population of each area for 1967 was inserted into this equation to calculate total Btu's per degree day for each area. Total Btu's per degree day multiplied by the average annual degree days gave the estimated metropolitan area energy consumption in Btu's. This value was apportioned among the three fuels--coal, oil and gas in proportion to the estimated ratio of consumption for the state in which the metropolitan area was located, based on fuel consumption data [Ref. 2]. The percentage distribution of fuels consumed by state is shown in Table H-1.

Since data were not available showing the distribution of boiler sizes for commercial and institutional heating plants by metropolitan area, a model plant was used for the estimation of emissions and control costs. Information available for St. Louis indicated that over 90 percent of the establishments clustered closely around a mean energy use of 816 thousand Btu's per degree day [Ref. 3]. This was adopted as the model plant for this study.

Table H-1

FUEL CONSUMPTION FOR COMMERCIAL AND INSTITUTIONAL HEATING, 1967
(PERCENTAGE DISTRIBUTION OF GAS, OIL, AND COAL BY STATE)

State	Percentage Distribution		
	Gas	Oil	Coal
Maine	0.0	97.6	2.4
New Hampshire	8.2	89.6	2.2
Vermont	0.0	99.5	0.5
Massachusetts	14.6	85.1	0.3
Rhode Island	23.8	76.2	0.0
Connecticut	18.6	80.4	1.0
New York	30.0	69.6	0.4
New Jersey	31.6	68.2	0.2
Pennsylvania	49.7	47.7	2.6
Delaware	25.1	72.8	2.1
Maryland	38.0	59.5	2.5
District of Columbia	26.0	71.2	2.8
Virginia	29.5	60.3	10.2
West Virginia	82.2	9.5	8.3
North Carolina	14.7	76.2	9.1
South Carolina	36.0	54.1	9.9
Georgia	72.4	23.7	3.9
Florida	27.1	70.3	2.6
Kentucky	66.8	24.4	8.8
Tennessee	62.5	18.2	19.3
Alabama	81.1	17.9	1.0
Mississippi	68.6	31.4	0.0
Ohio	76.7	17.7	5.6
Indiana	53.5	40.8	5.7
Illinois	61.3	30.0	8.7
Michigan	64.2	28.6	7.2
Wisconsin	37.8	47.0	15.2
Minnesota	49.4	45.8	4.8
Iowa	62.8	34.0	3.2
Missouri	71.6	28.4	0.0
North Dakota	34.9	64.1	1.0
South Dakota	45.5	51.3	3.2
Nebraska	75.5	23.9	0.6
Arkansas	78.1	21.9	0.0
Louisiana	85.6	14.4	0.0
Oklahoma	75.0	25.0	0.0
Texas	78.9	21.0	0.1
New Mexico	77.0	20.0	3.0
Kansas	78.7	21.3	0.0
Montana	67.9	25.7	6.4
Idaho	31.8	57.2	11.0
Wyoming	72.1	26.5	1.4
Utah	73.8	20.5	5.7
Colorado	77.8	16.1	6.1
Washington	26.2	70.5	3.3
Oregon	22.3	75.2	2.5
Arizona	84.7	11.7	3.6
Nevada	49.7	43.2	7.1
California	95.2	4.8	0.0
Alaska	24.9	72.2	2.9
Hawaii	0.0	100.0	0.0

Source: Reference 2

Particulate and SO_2 emissions were calculated in each metropolitan area, using the uncontrolled emission rates shown in Table H-2.

Table H-2

UNCONTROLLED EMISSION RATES FOR COMMERCIAL-INSTITUTIONAL SPACE HEATING

Fuel	Emission Rates	
	Particulate	SO_2
Coal	20 lbs/ton	38(S)[a] lbs/ton
Oil	8 lbs/1000 gal.	157(S)[a] lbs/1000 gal.
Gas	19 lbs/10^6 cf	1.4 lbs/10^6 cf

[a] "S" is sulfur content of fuel expressed in percentage.

Evaluation of the estimated emissions for the model plant in each metropolitan area showed that uncontrolled coal burning units produced particulate emissions in excess of the standard and SO_2 emissions in excess of the standard when burning coal with more than one percent sulfur content. It was assumed that gas cleaning was not an appropriate control measure for these emissions. Therefore, the control method specified for cost analysis was use of substitute fuels for all existing coal-burning installations. Installations burning gas or oil meet the standards. For simplicity, it was assumed that gas and oil were substituted for coal in proportion to the established consumption of those fuels.

IV. CONTROL COSTS FOR 1967 BASE YEAR

Control costs were calculated on the basis of the difference in fuel cost plus the conversion cost shown in Table H-3.

Table H-3

CONVERSION COSTS FOR COMMERCIAL-INSTITUTIONAL SPACE HEATING

Substitute Fuel	Conversion Costs	
	Investment ($)	Annual Cost ($)
Gas	1600	320
Oil	2000	400

The estimated costs of controlling emissions from sources operating in 1967 are shown in Table H-4.

V. CONTROL COSTS RESULTING FROM GROWTH

It was assumed for the purpose of this study that all heating plants installed after 1967 would not be coal-fired and accordingly, would be in compliance with the assumed emission standards. In light of this assumption, no additional compliance costs resulting from growth have been calculated for fiscal years 1971 through 1975.

Table H-4

COMMERCIAL-INSTITUTIONAL HEATING PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	64	675	--	--	0.0	0.0	--	--						
FY71	63	672	--	--	1.8	0.5	--	--	1.3	1.7	2.3	1.5	0.2	0.2
FY72	55	650	--	--	9.0	3.7	--	--	5.8	7.7	10.4	1.1	1.5	2.0
FY73	42	612	--	--	34.3	9.3	--	--	8.9	11.9	16.1	2.8	3.8	5.1
FY74	33	585	--	--	48.8	13.3	--	--	5.6	7.4	10.0	4.0	5.4	7.3
FY75	31	580	--	--	51.5	14.0	--	--	1.5	2.0	2.7	4.3	5.7	7.7
Total -									23.1	30.7	41.5	13.7	16.6	22.3

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

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Appendix I

Residential Heating Plants

Appendix I

Residential Heating Plants

I. INTRODUCTION

Residential heating plants, especially coal-fired furnaces in single-family homes and apartment houses, are significant sources of particulates and sulfur oxides. In 1967, the United States contained an estimated 58 million residential heating plants with about 35 million of these located within the 100 metropolitan areas. These 100 areas contained an estimated 2.2 million dwelling units using coal, 10.9 million using oil, and 17.6 million using gas; some are heated with electricity.[1/] Coal, and to some extent, oil account for both types of emissions; however, the emissions from oil burning do not exceed the maximum limit of the applicable regulations for either particulates or sulfur oxides.

II. CONTROL OF EMISSIONS

Because of the small size of residential heating plants, the most practical control strategy is switching to a different fuel or converting to electric heating. Under the plan assumed as a basis for estimating emission control costs, coal would be replaced by other fossil fuels or electricity. These changes were prorated on the basis of the 1967 pattern of usage in each area. In 1967, national emissions from residential heating plants amounted to 314 thousand and 1,530 thousand tons of particulates and sulfur oxides, respectively. The 1967 emissions for the 100 metropolitan areas were 163 thousand and 1,043 thousand tons of particulates and sulfur oxides, respectively.

[1/] Projected from corresponding 1960 data and adjusted for trends or new installations and conversions as shown by associated statistics provided by the Electric Heating Association and the American Gas Association (also Refs. 1, 2, and 3).

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III. DISCUSSION AND EVALUATION OF TECHNICAL DATA USED IN COST ESTIMATION

The method used in estimating the cost of controlling air pollution caused by residential heating plants was as follows:

a) Estimate number of occupied dwelling units in each metropolitan area in 1967.
b) Allocate occupied dwelling units by type of fuel consumed.
c) Calculate consumption of coal, oil, and gas for each metropolitan area.
d) Calculate particulate and SO_2 emissions on the basis of fuel consumption.
e) Determine whether calculated emissions are within the standards assumed herein.
f) Determine appropriate control method to achieve compliance with specified standards.
g) Determine the investment and operating cost differential resulting from compliance.

The number of occupied dwelling units in each metropolitan area in 1960, classified by fuel used in heating, was obtained. In order to project this to 1967, data were collected on the relative use of oil, gas, and electricity as the heating fuel in new construction and the rate of conversions from one fuel to another.[2] The number of dwelling units in each metropolitan area was projected by dividing the projected population by the median number of persons per dwelling unit (based on the 1960 census). The increase in the number of occupied dwelling units, 1960 to 1967, then was allocated to fuel type using construction and fuel conversion data for each state, and the resultant additional units using each fuel were added to the 1960 totals.

Given the number of occupied dwelling units in each metropolitan area for 1967 classified by fuel used, and using the method outlined by Ozolins [Ref. 4], the consumption of each fuel was calculated:

a) Assumptions
   1) Heating values: coal, 26×10^6 Btu/ton; oil, 145,000 Btu/gallon; gas, 1,000 Btu/cubic foot.
   2) Efficiency of heating plant: coal, 50%; oil, 60%; gas, 75%.
   3) Heating requirement: 115,200 net Btu/dwelling unit-degree-day.

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[2] Data obtained from the Electric Heating Association, the American Gas Association and References 2 and 3.

4) Average number of annual heating degree days for the nation equals 4600.

5) Average dwelling unit of 5 rooms.

b) Derived fuel requirements

1) 0.0012 ton coal/dwelling unit-degree day, Fc.

2) 0.18 gallon oil/dwelling unit-degree, Fo.

3) 2215 cubic feet gas/dwelling unit-degree day, Fg.

To calculate the amounts of each fuel used in each metropolitan area, the following equation was used:

$$Ti = N \times Fi \times D \times S/5$$

where; for each region:

Ti is the total quantity of the particular fuel type (i) used;

N is the number dwelling units;

Fi is the derived fuel requirement for each dwelling unit per degree day;

D is the average annual degree days; and

S is the average dwelling unit size in rooms.

Particulate and SO_2 emissions were calculated from the above estimated consumption data and the uncontrolled emission rates given in Table I-1.

Table I-1

UNCONTROLLED EMISSION RATES

Fuel Type	Emission Rate	
	Particulate	SO_2
Coal	20 lbs/ton burned	38 (S)[a] lbs/ton burned
Oil	12 lbs/1000 gal. burned	157 (S)[a] lbs/1000 gal burned
Gas	19 lbs/10^6 cu. ft. burned	0.4 lbs/10^6 cu. ft. burned

[a] "S" is sulfur content expressed as percentage.

Source: Reference 5.

Analysis of particulate emissions revealed that areas with less than 25 heating degree days on the average January day would be in compliance with the specified standard. The SO_2 emission standard was met in areas using coal with 1 percent or less sulfur by weight. These criteria were met in 8 regions: (29) Birmingham, (32) Chattanooga, (43) Charlotte, (65) Nashville, (72) Greensboro, (76) Knoxville, (81) Norfolk, (97) Raleigh.[3/] In another

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[3/] See Appendix B for list of 100 areas.

36 areas, coal consumption was estimated to be negligible or zero. Particulate and SO_2 emissions from oil and gas combustion were in compliance with specified standards. Control was required in the remaining 56 areas.

It was assumed that the only feasible control technique for residential heating was a change in fuel. Therefore, elimination of excessive pollutant emissions from coal combustion required substitution of oil, gas, or electricity, and control costs were calculated for this substitution. The coal consumption eliminated was allocated on a Btu basis to oil, gas, or electricity in proportion to the estimated consumption of these fuels already existing in each metropolitan area and translated into gallons, cubic feet, or kilowatt hours, respectively.

IV. COST ESTIMATION

Data on the price of coal for domestic use were not available for most metropolitan areas; however, estimated industrial prices were available for some metropolitan areas [Ref. 6]. Estimates of industrial prices for the remaining metropolitan areas were made by estimating differentials in cost due to transportation from the region of origin. It was then assumed that the price to commercial consumers would average 2 1/2 times the industrial price and that the price to residential users would average $5 per ton more than the commercial price. Thus, residential user prices were estimated which were felt to reflect reasonable differences in the cost of coal by metropolitan area.

Oil and gas prices based on the Ernst and Ernst report [Ref. 6] were used to estimate prices for metropolitan areas not covered. Electric rates were taken from the Federal Power Commission's Electric Rate Book [Ref. 7], using metropolitan area rates, where separately stated, or the lowest residential rate applicable.

Using these prices, the differences in the cost to consumers resulting from substituting fuels were calculated and aggregated for each metropolitan area. In a number of metropolitan areas, fuel substitution resulted in a reduction in cost. Standard costs for conversion, presented in Table I-2, were assumed and the annualized cost of conversion added to the differential fuel cost by metropolitan area.

Table I-2

CONVERSION COSTS FOR RESIDENTIAL HEATING

Conversion Unit	Investment Cost ($)	Annual Cost ($)
Gas	250	50
Oil	400	80
Electricity	650	130

Control cost estimates for residential heating plants existing in 1967 are presented in Table I-3.

V. CONTROL COSTS RESULTING FROM GROWTH

Industry data indicate that new residential construction using coal as the heating fuel is virtually zero within the 100 areas. Therefore, it is assumed that all residential construction since 1967 is in compliance with the applicable standards and no additional costs resulting from growth were calculated.

Table I-3

RESIDENTIAL HEATING PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	163	1043	--	--	0.0	0.0	--	--	26.3	35.1	47.4	7.4	9.8	13.2
FY71	155	1004	--	--	5.0	3.7	--	--	96.8	129.0	174.0	33.7	45.0	60.7
FY72	126	887	--	--	22.6	16.7	--	--	142.0	190.0	256.0	65.2	87.0	117.0
FY73	92	705	--	--	43.9	32.4	--	--	105.0	140.0	189.0	78.7	105.0	142.0
FY74	77	635	--	--	52.9	39.1	--	--	41.6	55.5	74.9	96.8	129.0	174.0
FY75	57	541	--	--	65.2	48.1	--	--						
Total -									411.7	549.6	741.3	281.8	375.8	506.9

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

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Appendix J

Kraft (Sulfate) Pulp Industry
(SIC No. 2611)

Appendix J

Kraft (Sulfate) Pulp Industry

I. INTRODUCTION

The pulp industry manufactures pulp from wood and other materials for use in making paper and related products. The several methods by which pulp can be produced are generally classified as either chemical or mechanical. Only the chemical methods, however, cause significant air pollution problems. Among the chemical pulp production methods, sulfite and sulfate (kraft) pulp plants account for the major proportion of all pulp production--about 75 percent of the total industry output. Sulfite production, although a potentially serious source of sulfur dioxide when waste liquor incineration is practiced, is not included in this study because the cost of control can be completely offset by the value of recovered heat and process chemicals.

In kraft pulp mills, four major processes emit significant amounts of particulates: process chemicals from recovery furnaces and smelt-dissolving tanks, lime from lime recovery kilns, and bark char from bark boilers. Recovery furnaces also emit sulfur oxides, but the best available estimates indicate that these emissions do not exceed the 500 ppm regulation limit assumed for this analysis.

In 1967, there were 113 kraft pulp plants in the United States with only 16 of these in the 100 metropolitan areas. The national and area capacities were 32.9 million and 4.1 million tons, respectively; production was 22.8 million tons for the United States and 2.8 million tons for the 100 areas with value of shipments amounting to $3.4 billion and $0.4 billion, respectively. Kraft pulp plants emitted a national total of 633 thousand tons of particulates in 1967; 109 thousand tons originated in the 100 areas.

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II. CONTROL OF EMISSIONS

Current (1967) average levels of particulate control for recovery furnaces, lime kilns, smelt-dissolving tanks, and bark boilers are 86, 80, 50 and 75 percent, respectively [Ref. 1]. These result in a weighted average industry control level of 81 percent. When the standards are implemented, the overall industry control level will reach 96.3 percent, resulting in emissions of 21 thousand tons from the 1967 base industry.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering approach taken to estimate air pollution control costs for the pulp and paper industry consisted of: (a) an evaluation of the various production processes commonly found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an evaluation to select the most satisfactory control systems to achieve the required levels.

The three most important classes of pulp-making operations from the standpoint of potential air pollutant emissions are: (a) the sulfate (kraft) process, (b) the sulfite process, and (c) the neutral sulfite semichemical process. The sulfite process is a potentially serious source of SO_2; however, several factors contributed to the omission of this process from this study. First, in those plants which do not practice waste liquor incineration, SO_2 emissions are practically negligible. In those plants practicing incineration, chemical and thermal recovery is economically attractive [Refs. 2,3]. Therefore, this report assumes that all sulfite plants have or will soon have chemical and thermal recovery systems which profitably reduce SO_2 emissions to less than the 500 ppm limit.

In neutral sulfite semichemical (NSSC) pulping, particulates are not a problem; therefore, NSSC pulping was not considered for the purposes of this study.

The kraft process, however, represents an emission source which must be considered. Particulate emissions from this pulping process are being emitted to the atmosphere in quantities exceeding the standard adopted for this study. The kraft pulping process includes the following unit processes: (a) black liquor recovery furnaces, (b) lime regeneration kilns, (c) smelt-dissolving tanks, and (d) bark boilers.[1/]

Uncontrolled rates of particulate emissions are presented in Table J-1.

Table J-1

UNCONTROLLED PARTICULATE EMISSION RATES

Process	Emission Rate (lb/ton air dried pulp)
Recovery furnace	150
Lime kiln	94
Smelt-dissolving tank	20
Bark boiler	18

Source: References 5 and 6.

The emissions from the recovery furnace and lime kiln consist mainly of very fine sodium and calcium salt fumes, while those of the smelt tank are very fine mists containing carbonates and sulfides of sodium. Presently, all of the processes are, on the average, controlled to some extent. Table J-2 presents estimated particulate control levels.

[1/] Non-bark burning boilers are also present, but are considered under industrial boiler sources.

Table J-2

ESTIMATED PARTICULATE CONTROL LEVELS AND EMISSION RATES AFTER CONTROL

Process	Control Eff. (percent)	Emission Rate After Control (lb/ton air dry pulp)
Recovery furnace	86	21.0
Lime kiln	80	18.7
Smelt-dissolving tank	50	10.0
Bark boiler	75	4.5

Based upon the process weight rate particulate emission standard, ultimate removal efficiencies were calculated for the various processes as a function of gas volume as presented in Table J-3.

The relationship between gas volume and production for each process is given in Table J-4.

To achieve the required control efficiency levels, the control systems presented in Table J-5 were selected.

The equipment costs data used in the analysis will be discussed in the next section of this report.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Data on location and total capacity of each kraft pulp mill [Ref. 7] and on the capacity of each lime recovery kiln within each mill [Ref. 8] were available for the 100 metropolitan areas. The data on total capacity of each mill were used along with data from a NAPCA survey [Ref. 9] to determine the capacity of recovery furnaces, smelt-dissolving tanks, and bark-burning boilers in each mill.

All recovery furnaces were assumed to be of equal size within a plant and to have an associated smelt-dissolving tank of corresponding capacity.

Table J-3

REQUIRED REMOVAL EFFICIENCIES FOR KRAFT PROCESSES[a]

Process	Gas Volume (10^3 acfm)	Percent Efficiency Required
Recovery furnaces	25	95.0
	75	97.8
	125	98.5
	175	98.9
	225	99.1
	275	99.3
	325	99.4
Lime kiln	5	96.9
	15	97.8
	25	98.2
	35	98.3
	45	98.6
	55	98.8
	65	98.9
	75	99.0
	85	99.1
	95	99.2
	105	99.3
Smelt-dissolving tanks	2.5	84.0
	7.5	93.2
	12.5	95.2
	17.5	96.0
	22.5	96.4
	55.0	98.8
Bark boilers[b]	16	93
	24	93
	32	93
	40	95
	48	95
	56	95
	64	96
	72	96
	80	97

[a] Gas volume data taken from a 1969 NAPCA summary of unpublished surveys; required efficiencies were calculated.

[b] Bark boilers were considered in this study as a process step; therefore, the more stringent process weight rate standard was applied instead of the Maryland Combustion Regulation.

Table J-4

GAS VOLUME VS. PRODUCTION FOR KRAFT PROCESSES

Process	Gas Volume Production (acfm/100 T/D)[a]
Recovery furnace	25,000
Lime kiln	3,200
Smelt-dissolving tank	3,100
Bark boiler	8,000

[a] 100 tons per day air-dried pulp.

Adapted from Reference 6.

Table J-5

CONTROL SYSTEMS SELECTED

Process	Control System	Pressure Drop
Recovery furnace	Venturi scrubber[a]	30" w.g.
Lime kiln	Venturi scrubber	20" w.g.
Smelt-dissolving tank	Venturi scrubber	10" w.g.
Bark boiler	Multi-cyclone	4-5" w.g.

[a] Assumed to follow existing electrostatic precipitator.

For each mill, a pair of equal-sized bark boilers were assigned a total capacity appropriate to the total mill capacity and a bark factor (tons of bark per ton of pulp) was used.[2/] A complete list of lime mud recovery kilns by size was obtained from Rock Products [Ref. 8].

The type of control varied with the type of process equipment. Recovery furnaces and smelt-dissolving tanks were assigned venturi scrubbers that use a weak black liquor scrubbing medium; lime kilns were assigned venturi scrubbers; and bark boilers were assigned specially-designed multicyclone collectors.

Control costs were calculated from the data in Tables J-6 through J-9. Gas volume - equipment cost and gas volume - annual operating cost relationships are presented for the various required control systems in Figures J-1 through J-7. Installed costs are 3 times the equipment costs for the black liquor scrubbers, 2 times for the wet scrubbers, and 2 times for the multicyclones. Annual costs are operating costs plus 20 percent of the investment. The resulting costs for controlling each mill were totalled for each of the 100 metropolitan areas.

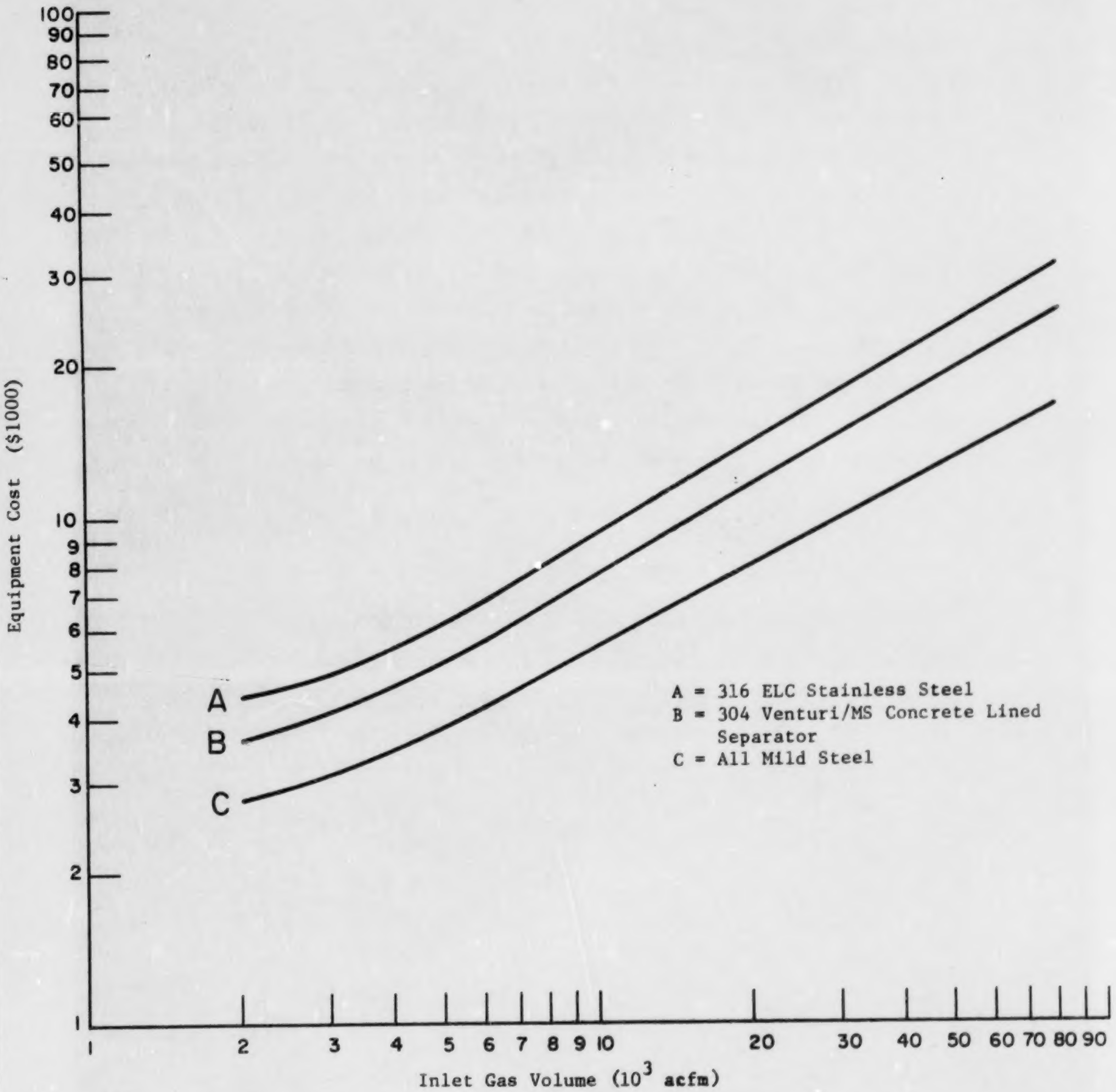
Table J-6

KRAFT RECOVERY FURNACE EMISSION CONTROL COSTS

Furnace Gas Volume (10^3 acfm)	Associated Capacity (tons/day)	Investment Cost ($1000)	Annual Cost ($1000)
25.0	96	92.0	20.1
75.0	290	123.0	48.6
125.0	485	198.0	78.1
175.0	680	258.6	94.7
225.0	870	309.0	130.0
275.0	1065	375.0	158.0
325.0	1260	420.0	180.4

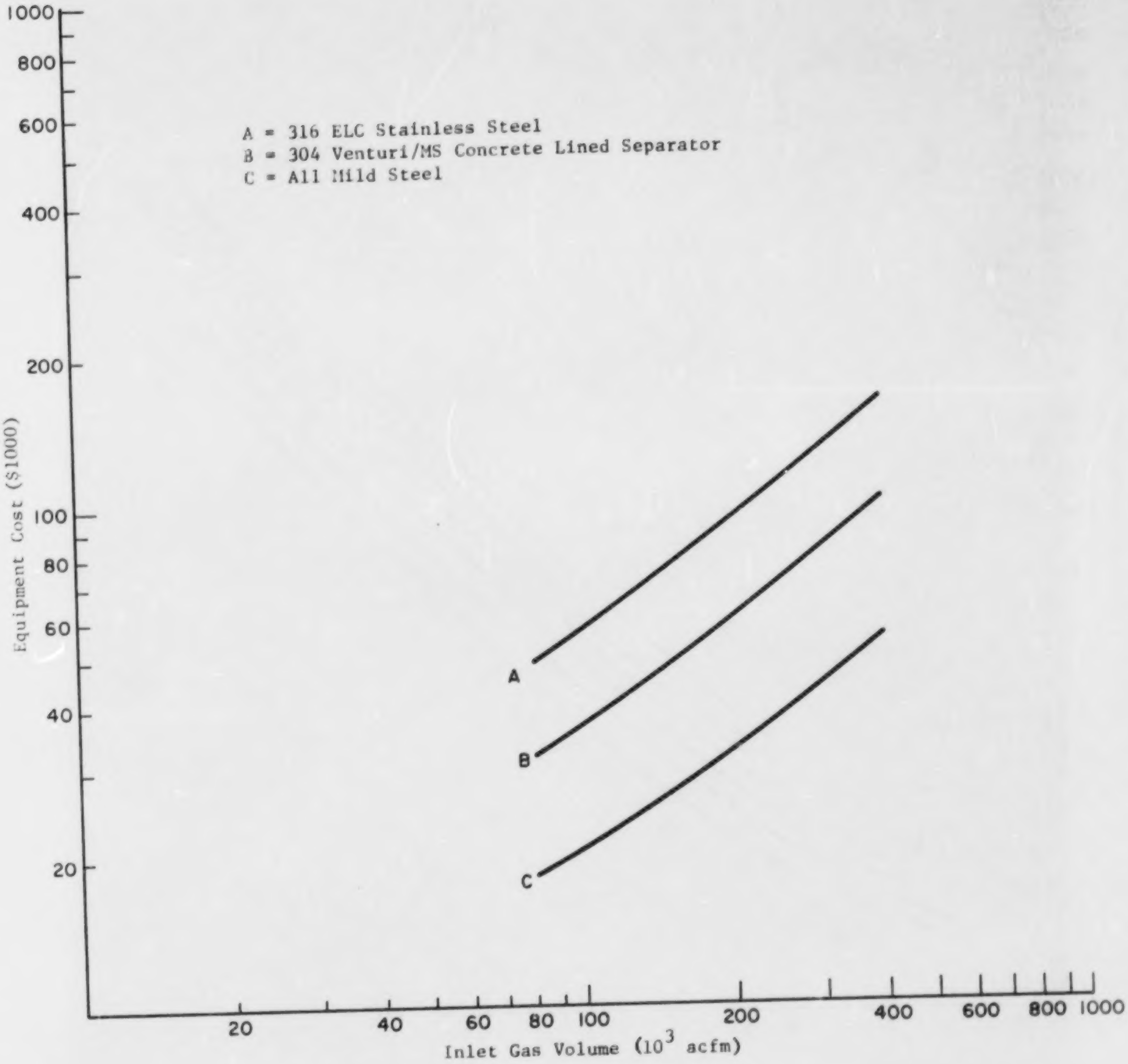
a Tons of air-dried pulp per day.

[2/] Calculated from the Sirrine report (see Reference 6).



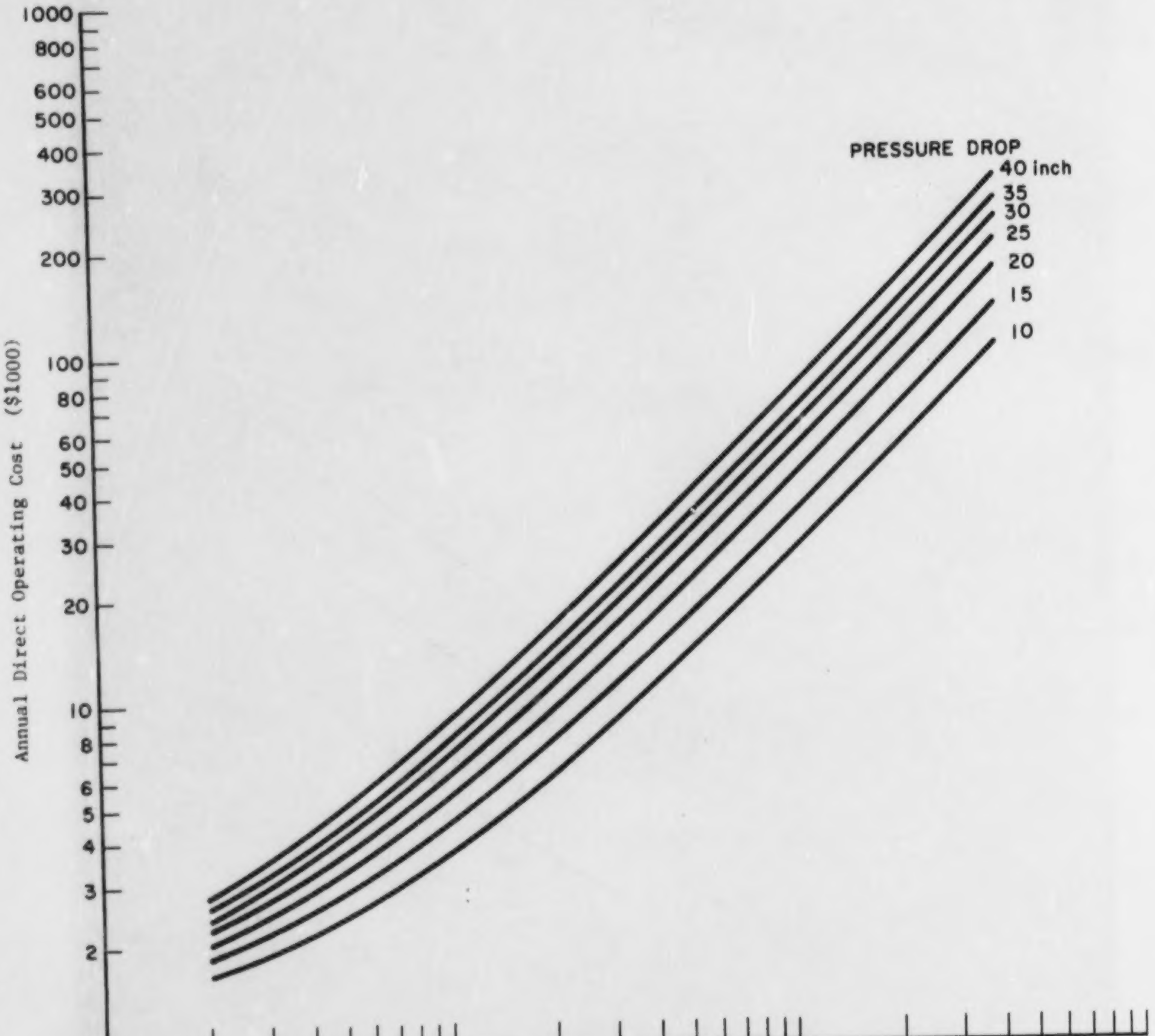
Source: Poly Con Corporation.

Fig. J-1. Equipment Cost for Venturi Scrubbers.



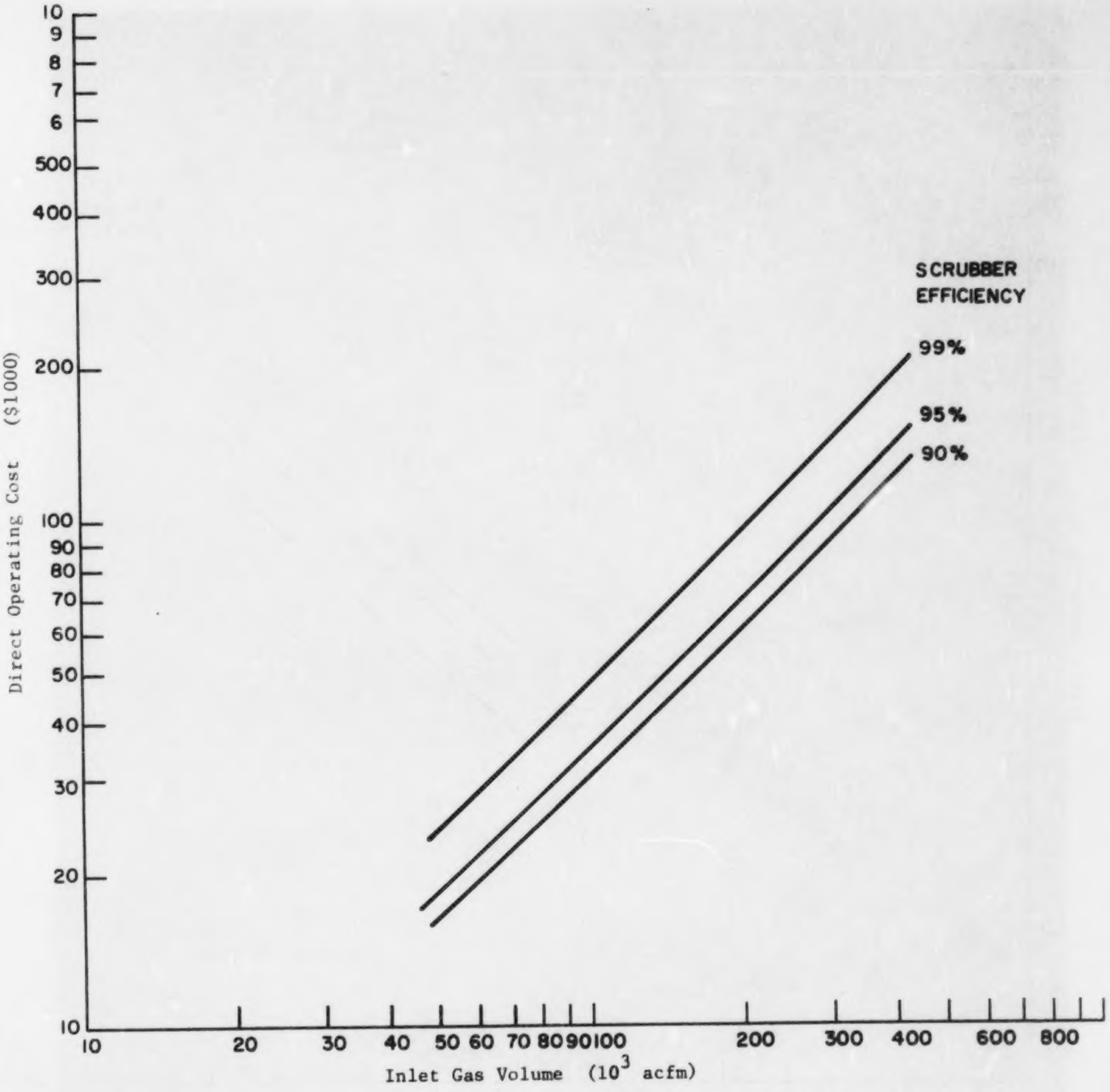
Source: Poly Con Corporation.

Fig. J-2. Equipment Cost for Venturi Scrubbers.



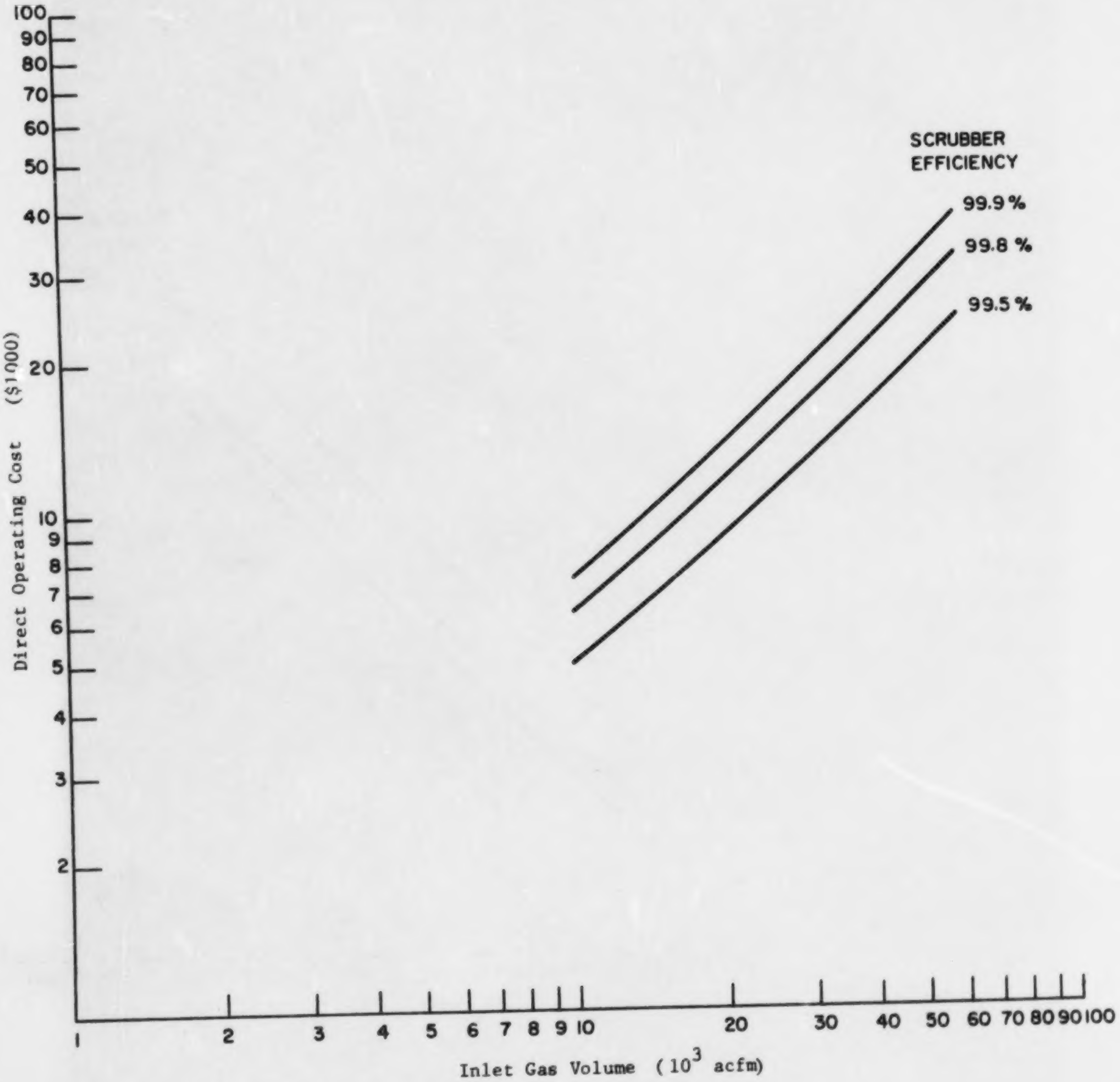
Source: Poly Con Corporation.

Fig. J-3. Annual Direct Operating Cost for Venturi Scrubbers.



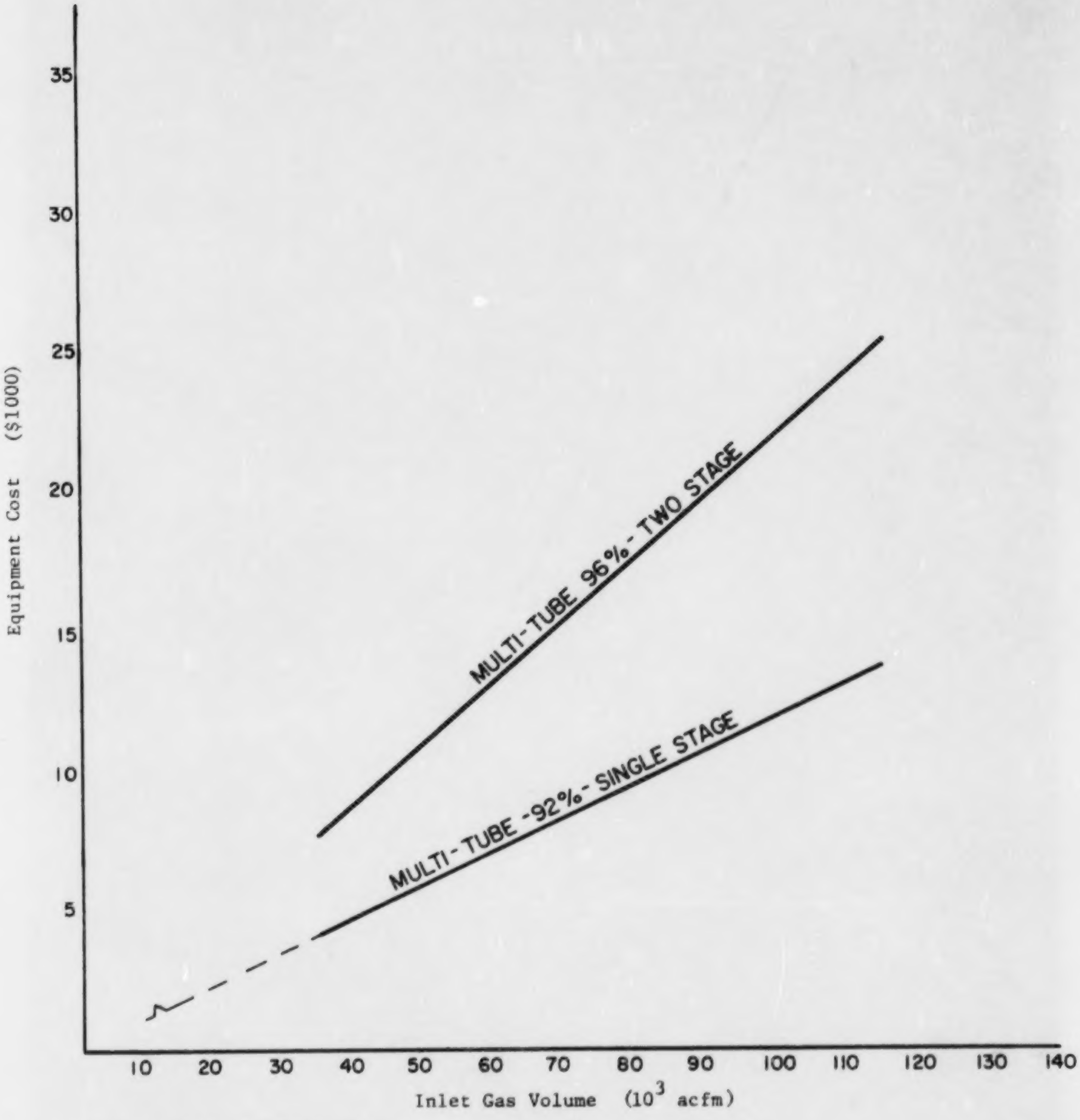
Source: Poly Con Corporation.

Fig. J-4. Annual Direct Operating Cost for Recovery Boiler Venturi Scrubbers.



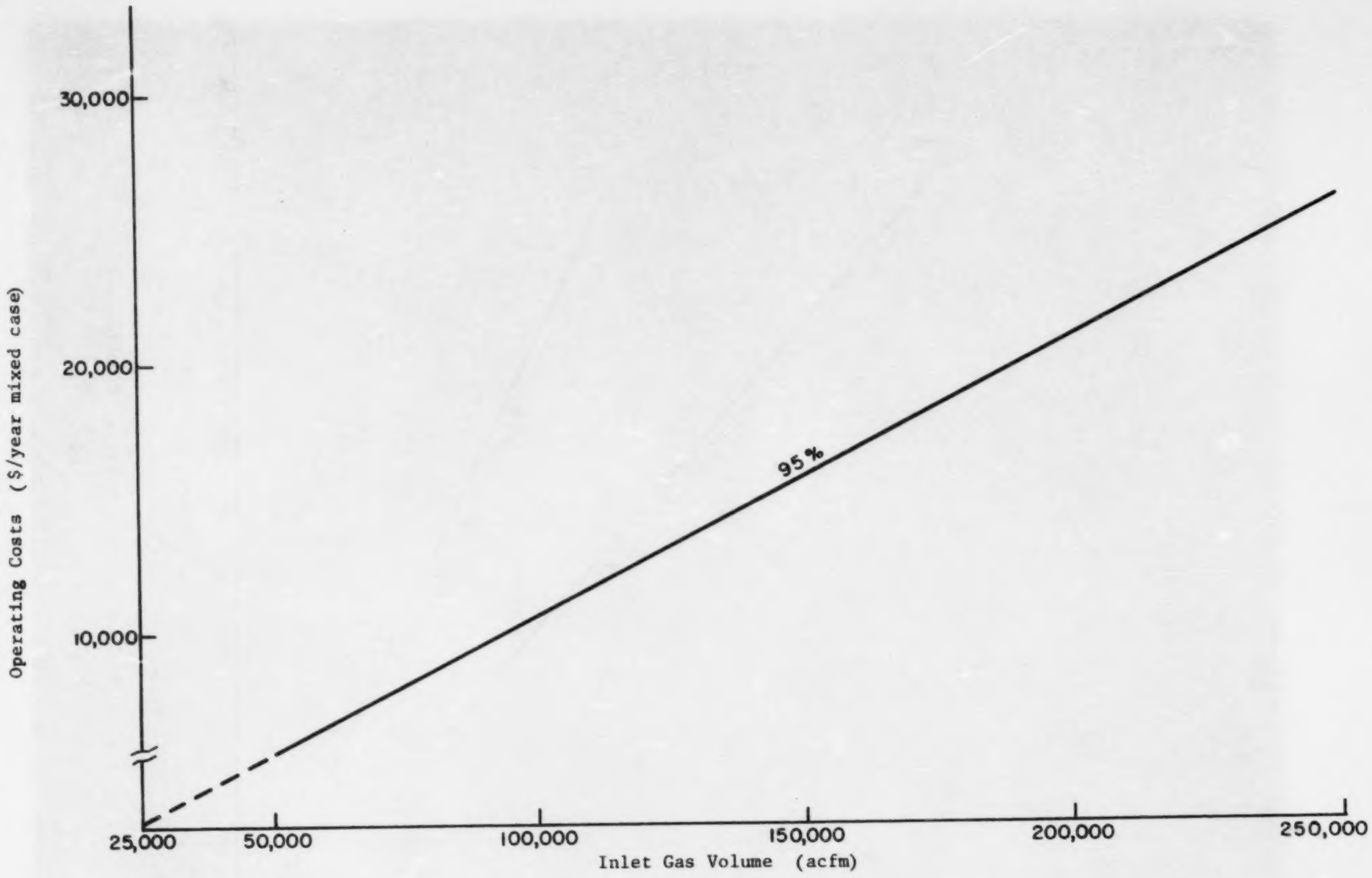
Source: Poly Con Corporation.

Fig. J-5. Annual Direct Operating Cost for Lime Kiln Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. J-6. Equipment Cost for Multi-tube Collectors.



Source: Poly Con Corporation.

Fig. J-7. Annual Operating Cost for Multi-tube Collectors.

Table J-7

ROTARY LIME RECOVERY KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Installed Cost ($1000)	Annual Cost ($1000)
100	14.0	8.8
150	17.3	12.0
200	20.0	15.0
250	22.5	17.7
300	25.0	20.5
350	26.5	23.4
400	28.0	26.5
450	29.7	29.2
500	32.0	31.4
550	34.6	34.3
600	37.8	37.6
650	40.9	41.2
700	44.0	45.2

Table J-8

KRAFT SMELT-DISSOLVING TANK EMISSION CONTROL COSTS

Tank Gas Volume (10^3 acfm)	Associated Capacity (tons/day)[a]	Investment Cost ($1000)	Annual Cost ($1000)
2.5	80	5.2	2.0
7.5	240	13.0	6.2
12.5	400	17.0	8.5
17.5	560	20.0	10.8
22.5	720	23.2	13.1
27.5	880	25.9	15.3
32.5	1040	28.7	17.6
37.5	1200	31.4	19.9
42.5	1360	34.0	22.1
47.5	1520	36.8	24.4
52.5	1680	39.6	26.7
55.0	1760	41.0	29.7

[a] Tons of air-dried pulp per day

Table J-9

KRAFT BARK BOILER EMISSION CONTROL COSTS

Boiler Gas Volume (10^3 acfm)	Associated Capacity (tons/day)[a]	Costs ($1000)	
		Investment	Annual
16	200	13.4	3.5
24	300	18.5	4.3
32	400	23.0	5.1
40	500	33.8	6.1
48	600	40.0	7.0
56	700	43.8	7.8
64	800	49.0	8.6
72	900	53.7	9.4
80	1000	57.5	10.1

[a] Tons of air-dried pulp per day.

B. Estimated Costs

The resulting costs that take into account existing controls were totalled for the 100 metropolitan areas and are shown in Table J-10. Annual control costs would average approximately $0.61 per ton of kraft pulp capacity.

The emission of particulates would be reduced from over 109 thousand tons in 1967 to approximately 21 thousand tons by 1975. Total investment would amount to $6.4 million with an ultimate annual cost of $2.4 million.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity but also for projected increased capacity in the kraft pulp industry beyond the base year of 1967. The projected growth costs were based on the expected ultimate overall control level of 96.3 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

Table J-10

KRAFT (SULFATE) PULP PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	109	--	--	--	81.0	--	--	--						
FY71	109	--	--	--	81.0	--	--	--	0.3	0.3	0.4	0.1	0.1	0.1
FY72	101	--	--	--	82.5	--	--	--	0.5	0.6	0.7	0.2	0.2	0.3
FY73	73	--	--	--	87.2	--	--	--	1.5	1.8	2.2	0.7	0.9	1.1
FY74	43	--	--	--	92.5	--	--	--	1.8	2.2	2.7	1.4	1.8	2.2
FY75	21	--	--	--	96.3	--	--	--	1.2	1.5	1.9	1.9	2.4	2.9
Total -									5.3	6.4	7.9	4.3	5.4	6.6

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

An average growth rate of 8.0 percent per year was assumed for the 1967 - FY 1975 period. This was based on the American Paper Institute estimates for the entire industry. The capacity estimates, derived from the production estimates, were based on achieving 90 percent utilization of capacity by FY 1975. The results of the cost analysis of controlling the new capacity are shown in Table J-11. As shown, the cost in each year reflects immediate control of the incremental capacity at ultimate control levels.

By 1975, without the act in effect, particulate emissions in the 100 areas would reach 164 thousand tons from the 1967 capacity plus the additional capacity added after 1967. With the act in effect, emissions would be reduced to 33 thousand tons.

Table J-11

KRAFT (SULFATE) PULP PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr)	ADDITIONAL PRODUCTION (thousand tons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	119	329	6	--	--	--	0.1	0.2	0.2	0.1	0.1	0.1
FY72	199	564	7	--	--	--	0.1	0.2	0.2	0.1	0.1	0.1
FY73	278	790	9	--	--	--	0.2	0.2	0.3	0.2	0.2	0.2
FY74	358	1016	11	--	--	--	0.2	0.2	0.3	0.2	0.3	0.3
FY75	438	1241	12	--	--	--	0.2	0.2	0.3	0.3	0.4	0.4
Totals -							0.8	1.0	1.3	0.9	1.1	1.1

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix K

Iron and Steel Industry
(SIC No. 3312)

Appendix K

Iron and Steel Industry

I. INTRODUCTION

In 1967, the capacity of the 141 iron and steel plants located in the United States was 165 million tons, and the annual national production of raw steel was 127 million tons. The annual value of shipments was $13.3 billion. For the 115 plants located in the 100 metropolitan areas, capacity was about 116 million tons. Production reached approximately 101 million tons with value of shipments amounting to $10.5 billion.

Several major processes are a part of the iron and steel industry. Coking is an important method of producing fuel for melting operations. Sintering aggregates or fuses iron ore into larger particles which are used in blast furnaces; blast furnaces produce iron in molten or pig form from iron ore. Iron and some scrap are then converted to steel in one of three types of steel furnaces: open hearth (which usually have oxygen lancing), basic oxygen, and electric arc. Scarfing is an operation to remove surface defects from steel. Of course, the industry employs many other processes, but the ones mentioned above are of major importance with respect to air pollution.

Estimates of control costs for the blast furnace operation are not included because the effluent gases are cleaned for use in other processes instead of being released into the air. Two other major processes, coking and scarfing, are also excluded from this analysis due to insufficient data to prepare even a minimally reliable cost estimate. The cost estimates that were prepared reflect the projected reduction in particulate emissions from all three types of steelmaking furnaces and from the sintering operations.

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II. CONTROL OF EMISSIONS

In 1967, in the 100 metropolitan areas particulates from these sources totalled about 1060 thousand tons and were controlled at an overall level of about 52.5 percent efficiency. The application of gas-cleaning equipment such as electrostatic precipitators and wet scrubbers can result in an overall collection efficiency among these facilities of about 95.5 percent, reducing emissions to 101 thousand tons by FY 1975.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering approach to estimating control costs for the iron and steel industry consisted of: (a) an evaluation of production processes within the industry, (b) an analysis of uncontrolled emission rates, present levels of control, and final levels as required by various standards adopted for this study, and (c) an evaluation to select the most satisfactory control systems to achieve required emission levels.

The processes considered for the cost analysis in this report were the following: open hearth furnace, basic oxygen furnace, electric arc furnace, and the sintering operation.

Particulate control levels are well below technically feasible levels resulting in annual national emissions of about 1.5 million tons. On the other hand, carbon monoxide, a potentially significant emission, is controlled to a great extent by burning in waste heat boilers or in nonproductive complete combustion of off-gases to convert the carbon monoxide to carbon dioxide. Consequently, only costs to increase the level of control of particulates are included.

Totally uncontrolled rates of particulate emissions vary from process to process. Table K-1 presents the emission rates for each process.

No one has attempted a comprehensive analysis of the present level of particulate control levels in the iron and steel industry. However, some information [Refs. 1, 2, 3], fragmentary as it is, was used to set average nationwide control levels for the various processes. These are presented in Table K-2. For this table and the rest of the discussion of present emission estimates, open hearth control facilities are assumed to have been installed only where oxygen lancing is practiced.

Table K-1

UNCONTROLLED PARTICULATE EMISSION RATES

Process	Emission Rate (lb/ton produced)
Open hearth (nonoxygen lanced)	7.3
Open hearth (oxygen lanced)	21
Basic oxygen	40[a]
Electric furnace	15[a]
Sintering (windbox)	20
Sintering (discharge)	22

[a] From the Battelle report [Ref. 2] and assumed to update the emission factors given in Reference 1.

Source: References 1 and 2.

Table K-2

PARTICULATE CONTROL LEVELS

Process	Controlled Production (percent)	Average Control Efficiency (percent)
Open hearth furnace	27	90
Basic oxygen furnace	92	90
Electric furnace	61	90
Sintering (windbox)	90	75
Sintering (discharge)	0	--

Required particulate removal efficiencies for the various processes were calculated as a function of process size on the basis of the process weight rate standard and are presented in Table K-3.

Table K-3

REQUIRED REMOVAL EFFICIENCIES FOR EMISSION SOURCES[a]

Emission Source	Capacity (tons/melt)	Required Efficiency (percent)
Open hearth furnace[b]	50	89.5
	100	91.4
	150	92.3
	200	94.0
	250	94.9
	300	95.6
	350	96.1
	400	96.4
	450	96.7
	500	97.1
	550	97.3
	600	97.5
Basic oxygen furnace	50	98.0
	100	99.0
	150	99.3
	200	99.4
	250	99.5
	300	99.6
Electric arc furnace	25	84
	50	87
	100	89
	150	92
	200	94
	250	95
	(tons/day)	(percent)
Sintering machine	1000	95.0
	2000	97.0
	3000	98.0
	4000	98.3
	5000	98.6
	6000	98.8
Sintering discharge	1000	95.0
	2000	97.0
	3000	98.0
	4000	98.5
	5000	98.7
	6000	98.9

[a] Based on process weight rate standard.

[b] All open hearth furnaces are assumed in this study to be oxygen lanced prior to installation of control equipment.

Based on these required removal efficiencies, as well as particle size distribution functions, the choice of feasible control systems was made for the various processes. From the set of feasible alternatives, industry practice and other expert opinion was used to arrive at the control system requirements shown in Table K-4.

Table K-4

SELECTED CONTROL SYSTEMS

Process	Control System	Comments
Basic oxygen furnace	venturi scrubber	50" w.g.
Open hearth furnace	venturi scrubber electrostatic precipitator[a]	50" w.g.
Electric arc furnace	fabric filter	high temperature
Sintering (windbox)	venturi scrubber	20" w.g.
Sintering (discharge)	venturi scrubber	10" w.g.

[a] At present, open hearth furnaces (all oxygen lanced) have a 50-50 combination of scrubbers and precipitators.

Control cost estimating relationships adopted from engineering analyses developed by the Swindell-Dressler Corporation for each process are discussed in the next section.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Estimating air pollution control costs for the iron and steel industry was extremely complex because of the number of processes requiring different control levels.

Data were available on capacities and locations of all furnaces [Ref. 4]. Sintering machine locations were known from Reference 4, but capacities had to be estimated from the known range of capacities (2000 to 6000 tons per day) and the reported grate dimensions which were assumed to be related to capacities.

Control cost data were obtained which presented investment and operating costs for the extreme ends of the expected capacity range [Ref. 5]. Intermediate levels and capacities were calculated for each process using a cost function:

$$y = ax^b$$

where: y = control cost;
x = capacity; and a and b are parameters that depend on each process.

Cost parameters for all furnace and machine types are presented in Table K-5.

All types of furnaces and machines were assumed to need some additional control. Basic oxygen furnaces were assigned high energy wet scrubbers; open hearth furnaces, half high energy wet scrubbers and half electrostatic precipitators; electric arc furnaces, fabric filters; sintering machine windboxes and discharges, medium energy wet scrubbers.

The 1967 average levels of control and the national percentages of capacity controlled were known for all furnaces and machines; regional data were lacking, however. Accordingly, the estimated relationship between national and regional control levels for the gray iron foundry industry [Ref. 6] was applied to the iron and steel industry.

The cost relationship for electric arc furnaces was calculated using data from Reference 5, assuming two furnaces exhaust into a single control system with appropriate staggering of operations. If possible, two furnaces of equal capacity were paired; if not, furnaces with no more than a 25 percent difference were paired.

Table K-5

COST ESTIMATING PARAMETERS[a]

Unit Operation	Control Equipment	Units of Capacity	Cost Estimating Parameters[a] "a" Investment		"b" Investment	
			Investment	Annual	Investment	Annual
Open hearth furnace	high energy venturi scrubber electrostatic precipitator	tons/melt tons/melt	8,308[b]	6,576[b]	0.7	0.7
Basic oxygen furnace	high energy venturi scrubber	tons/melt	35,775	16,318	0.7	0.8
Electric arc furnace	fabric filter	tons/melt	12,902	8,400	0.7	0.7
Sintering (windbox)	medium energy venturi scrubber	tons of sinter/day	837	518	0.8	0.7
Sintering (discharge)	medium energy venturi scrubber	tons of sinter/day	15,835	5,541	0.3	0.3

---

[a] The cost function is $y = ax^b$, where y = control cost, x = capacity, and "a" and "b" are cost parameters that depend on the type of process. The same function was applied to the calculation of both annual and investment costs by simply using the appropriate a's and b's. To illustrate the use of the parameters, suppose that it is required to determine the investment and annual cost of controlling a basic oxygen furnace with a capacity of 400 tons per melt. The investment cost (y) is therefore $\$35,775\ (400)^{0.7} = \$2.36$ million with an annual cost(y) = $\$16,318\ (400)^{0.8} = \$1.96$ million.

[b] For all open hearth furnaces, the b parameters for both types of control equipment were the same, so a single cost function, with the average of two a's was used. Since the number of this type furnace is large in most metropolitan areas, little, if any, effect on total regional cost is expected from this simplification of calculations.

Control costs for electric arc furnaces were calculated using the $y = ax^b$ cost function; when two furnaces of different capacities were controlled, the larger capacity was assumed. Control costs for single furnaces were calculated by dividing the control cost for two furnaces (each of which has a capacity equal to the single furnace) by 1.4 to allow for a reduced ducting and blower requirement as well as reduced average load. These calculations yielded basic costs at the Swindell-Dressler efficiency level [Ref. 5]. The basic costs were then adjusted to the control efficiency required by the selected standards of this study by using a cost multiplier as described in Chapter 2, "Study Methodology." The cost multiplier was again applied to furnaces to which existing control levels had been assigned to obtain the cost for the required control efficiency. When the difference between the costs for required efficiency and current efficiency was positive, it was recorded as the net control cost; no negative costs were recorded, although they did occasionally occur where the present level of control exceeded the standard.

B. Estimated Costs

The resulting costs, which take into account existing controls, were totalled for the 100 metropolitan areas; these are shown in Table K-6. Control costs would average approximately $1.76 per ton of steelmaking capacity when the plan is fully implemented.

The emission of particulates would be reduced from over 1 million tons in 1967 to approximately 101 thousand tons by 1975. The investment cost for this level of control would total $319.5 million, with an annual cost of $204.4 million in 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for projected increased capacity in the iron and steel industry beyond the base year of 1967. The projected growth costs were based on the required ultimate control level for each process. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An expected growth rate through FY 1975 of 4.5 percent per year was used [Ref. 2]. The capacity estimates, derived from the production estimates, were based on achieving 90 percent utilization of capacity by FY 1975.

The results of the analysis of costs for controlling additional production facilities are shown in Table K-7. As shown, costs in each year reflect immediate control of incremental capacity; cumulative emissions shown in the table reflect compliance with the emission standards assumed herein. By 1975, without the act in effect, emissions in the 100 areas would reach 1420 thousand tons of particulates from the 1967 capacity plus the additional capacity added after 1967. With the act in effect, emissions would be reduced to 134 thousand tons.

Table K-6

IRON AND STEEL PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	1060	--	--	--	52.5	--	--	--						
FY71	986	--	--	--	55.8	--	--	--	17.1	24.5	31.8	11.0	15.7	20.4
FY72	638	--	--	--	62.8	--	--	--	65.1	93.1	121.0	52.2	74.7	97.1
FY73	258	--	--	--	88.4	--	--	--	86.3	123.3	160.2	106.9	152.8	198.6
FY74	127	--	--	--	94.3	--	--	--	46.1	65.9	85.7	136.1	194.4	252.8
FY75	101	--	--	--	95.5	--	--	--	8.9	12.7	16.5	143.0	204.4	265.7
Total -									223.5	319.5	415.2	449.2	642.0	834.6

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table K-7

IRON AND STEEL PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/year)	ADDITIONAL PRODUCTION (thousand tons/year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	15,788	15,908	15	--	--	--	10.3	14.7	19.2	6.6	9.4	12.2
FY72	20,299	20,453	20	--	--	--	15.0	21.4	27.8	16.2	23.1	30.1
FY73	24,810	24,998	24	--	--	--	17.0	24.3	31.6	27.1	38.7	50.3
FY74	29,321	29,543	29	--	--	--	13.1	18.8	24.4	35.5	50.7	65.9
FY75	33,832	34,088	33	--	--	--	9.5	13.6	17.7	41.6	59.4	77.3
Totals -							64.9	92.8	120.7	127.0	181.3	235.8

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix L

Gray Iron Foundry Industry
(SIC No. 3321)

Appendix L

Gray Iron Foundry Industry

I. INTRODUCTION

Gray iron foundries produce castings, such as machine and automobile parts, from gray iron, pig and scrap. The foundries are generally small, competitive businesses and nearly half of them are captive (owned by other businesses). To melt iron for casting, the industry generally uses three types of furnaces: electric arc and electric induction furnaces, which account for only 7 percent of the metal used, and cupolas which use the remaining 93 percent.

Since electric arc and electric induction furnaces emit relatively small amounts of pollutants and are fewer in number than cupolas, they were not included in this analysis.

In 1967, the national capacity for the 1,279 gray iron foundries was about 17.0 million tons. Production was 14.3 million tons, and the value of shipments was about$2.7 billion nationally and $1.7 billion within 100 metropolitan areas. The 661 foundries within the 100 areas with cupolas had a capacity of about 10.0 million tons and accounted for 8.7 million tons, or 61 percent of the total production.

Nationally in 1967, foundries with cupolas emitted an estimated 217 thousand tons of particulates and 3,200 thousand tons of carbon monoxide. In 100 metropolitan areas, they emitted 94 thousand tons of particulates and 1,250 thousand tons of carbon monoxide. Particulates from cupolas include dust, fumes, and smoke; about 10 percent of the exhaust gas, by volume, is carbon monoxide. With no control, about 17.4 pounds of particulates and 250 pounds of carbon monoxide are emitted for each ton of metal charged.

II. CONTROL OF EMISSIONS

Gas-cleaning equipment, such as wet scrubbers, in combination with afterburners can reduce the emission levels of particulates and carbon

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monoxide from cupolas to achieve compliance with the process weight rate standard for particulates and 95-percent removal for carbon monoxide. The regulations selected for this report would require the industry to increase its present average removal efficiency of 12 percent for particulates to 90 percent. Control of carbon monoxide, presently 18 percent, would be increased to 95 percent.

III. DISCUSSION AND EVALUATION OF DATA USED IN COST ESTIMATIONS

The basic data and information required to estimate air pollution control costs for the gray iron industry consisted of: (a) an evaluation of the various production processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the two standards adopted for this industry, (c) an engineering evaluation to select the most satisfactory control systems to achieve the required levels.

To date, the foundry industry has been a consistent user of high efficiency control equipment on its numerous in-plant dust problems in sand preparation, shakeout, abrasive cleaning and grinding operations. However, equipment to control the fume-laden gases from the melting operation has been installed in only a few locations.

Data on the present levels of control for particulates and carbon monoxide were obtained from a joint NAPCA-Department of Commerce survey. From these data, regional control level estimates on a cupola by cupola basis were made. Nationally, the overall control levels for particulates and carbon monoxide are 12 and 18 percent, respectively.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Two bodies of data were available to estimate costs of controlling emissions from cupolas in gray iron foundries. Data describing features of all gray iron foundries that operate cupolas were obtained by the Department of Commerce during 1968 via a mail survey. The information gave the location of all plants and the number of cupolas and some facts on emission controls presently installed for most plants. Cupola capacity ratings were not reported.

A representative sample of 67 foundries with cupolas was visited by NAPCA personnel to obtain extensive data on control systems. The collected data included information about investment and annual costs. From the sample survey, information on the sizes of cupolas in each plant was used to derive a distribution by size for the total industry. Data from the sample survey were also subjected to statistical analyses to relate costs to cupola control factors. Venturi scrubbers were selected as the particulate control device. For venturi scrubbers, costs were a function of two factors, gas volume and pressure drop. Sample data were also used to estimate gas volume as a function of melt rate. Investment and annual costs for venturi scrubbers are given in Table L-1. Afterburners were selected as the control device for carbon monoxide. However, the data from the survey, as presented in Table L-1, does include costs of installing and operating afterburners. Therefore, separate cost estimates were not made. By using these cost estimates and the distribution of cupolas, an average cost per control system was estimated.

When a foundry operates two cupolas of approximately the same capacities one emission control system is used for the pair. It was assumed that, where possible, one system would serve two cupolas. The data on foundries in each area were screened, taking into account cupolas that could be paired, to determine the number of systems required. These estimates and the estimate of average control system cost were then used to calculate an estimate of the investment cost for each area.

Table L-1

CUPOLA EMISSION CONTROL COSTS

Cupola Size (tons/hour)	Number of Cupolas	Control Costs ($1000)	
		Investment	Annual
2.5	232	103.5	31.2
7.5	323	179.0	54.0
12.5	279	246.7	74.5
17.5	211	318.4	96.1
22.5	139	386.2	116.6
37.5	20	457.8	138.2
32.5	0	529.4	159.8
37.5	0	604.9	182.6
42.5	48	678.1	204.7
47.5	29	752.0	227.0

Annual costs were estimated by multiplying the investment cost by 0.302. This factor was determined by statistical analysis of survey data and the estimates allow, in accordance with industry practice, about 18 percent for depreciation and other oapital-related charges. Annual depreciation and capital costs for other sources in this study except solid waste disposal allow 20 percent.

In those cases of foundries reporting installed control systems, it was assumed that presently installed mechanical collectors would be replaced by venturi scrubbers but that fabric filters, wet scrubbers, and the one reported electrostatic precipitator would be adequate. No credit was allowed in the cost estimates for the value of mechanical collectors that would be replaced.

B. Estimated Costs

The resulting costs, which include credits for existing controls, were totalled for the 100 metropolitan areas and are shown in Table L-2. Control costs would average approximately $4.91 per ton of annual gray iron capacity when the plan is fully implemented.

The emission of particulates would be reduced from over 94 thousand tons in 1967 to about 11 thousand tons in 1975, while the emission of carbon monoxide would be reduced from about 1,250 thousand tons to about 76 thousand tons. The investment cost during this period would amount to $172.7 million and an annual cost of $49.0 million.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for additional capacity in the gray iron industry beyond the base year of 1967. The projected growth costs were based on the expected ultimate average control level of 90 percent for particulates and 95 percent for carbon monoxide. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An average annual growth rate of 4.5 percent was used to estimate the increase in production during the period 1967 to FY 1975 [Ref. 2]. The capacity estimates were based on the production estimates and on achieving 90 percent utilization of capacity by FY 1975.

The costs of controlling the additional capacity are shown in Table L-3. As shown, costs in each year reflect immediate control of the incremental capacity. Without the act in effect it is estimated that by 1975 emissions in the 100 areas from the 1967 base plus the additional capacity would amount to 129 thousand tons of particulates and 1,720 thousand tons of carbon monoxide; with the act, these emissions would be limited to 15 and 104 thousand tons, respectively.

Table L-2

GRAY IRON FOUNDRIES

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	94	--	--	1250	12.0	--	--	18.0						
FY71	90	--	--	1250	19.2	--	--	18.0	4.5	7.0	9.4	1.3	2.1	2.8
FY72	71	--	--	1040	36.2	--	--	32.0	24.0	37.0	50.0	8.6	13.3	17.9
FY73	40	--	--	545	64.1	--	--	64.4	43.9	67.6	91.3	20.4	31.4	42.4
FY74	18	--	--	182	83.8	--	--	88.2	29.0	44.6	60.2	29.1	44.8	60.6
FY75	11	--	--	76	90.0	--	--	95.0	10.7	16.5	22.3	31.9	49.0	66.2
Total -									112.1	172.7	233.2	91.3	140.6	189.9

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table L-3

GRAY IRON FOUNDRIES

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (tons/hour melt rate)	ADDITIONAL PRODUCTION (thousand tons/year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	1,750	1,530	1	--	--	13	6.2	9.5	12.8	1.8	2.7	3.6
FY72	2,250	1,960	2	--	--	17	8.6	13.3	18.0	4.2	6.5	8.8
FY73	2,750	2,400	3	--	--	20	11.1	17.1	23.1	7.4	11.4	15.4
FY74	3,250	2,830	3	--	--	24	9.2	14.2	19.2	10.0	15.4	20.8
FY75	3,750	3,270	4	--	--	28	7.0	10.7	14.4	12.0	18.5	25.0
Totals -							42.1	64.8	87.5	35.4	54.5	73.6

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix M

Primary Nonferrrous Metallurgical Industry
(Primary Aluminum Reduction; Copper, Lead, and Zinc Smelting)
(SIC Nos. 3331-3334)

Appendix M

Primary Nonferrous Metallurgical Industry
(Primary Aluminum Reduction; Copper, Lead, and Zinc Smelting)

I. INTRODUCTION

The primary metal plants of the nonferrous metallurgical industry produce aluminum, copper, lead, and zinc from raw or refined ore with a variety of operations: the smelting of copper, lead, and zinc from ore; the refining of much of this metal into higher purity metal; the reduction of alumina (refined aluminum ore) to aluminum; and the refining of aluminum by several processes.

Of the pollutants considered in this study, only sulfur dioxide is emitted in significant quantities by the smelting and refining of copper, lead, and zinc. Even though the potential for particulate emissions from these sources is significant, these industries have controlled them at a level of at least 95 percent efficiency, which meets the requirements of the process weight rate standard. Alumina reduction is not a major source of sulfur dioxide; however, the electrolytic cells (pots) in which reduction takes place and the associated operations with the pots emit large amounts of particulates, including fluorides. Emissions from aluminum refining are unknown but are thought to be small in comparison with those from reduction.

In 1967, the capacity of the 64 plants in the United States was 16.7 million tons and production reached 6.4 million tons. For the 12 plants in the 100 areas, capacity was 3.4 million tons with production of 1.2 million tons. The value of shipments for the United States and the 100 areas was $3.4 billion and $0.6 billion, respectively. Particulate emissions amounted to 95 thousand tons for the United States and 22 thousand tons for the 100 areas. Sulfur dioxide was emitted in the amounts of 3848 thousand tons in the United States and 144 thousand tons in the 100 areas.

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II. CONTROL OF EMISSIONS

The analysis indicated the need for increased control of sulfur dioxide emissions from copper, zinc, and lead plant operations and of particulate emissions from aluminum plants. Current average sulfur dioxide removal efficiencies of 49 percent for copper, lead, and zinc plants can feasibly be increased to 98.9 percent; however, even this level will not lead to complete compliance with the requirement of a 500 ppm maximum sulfur oxide concentration assumed for this report. Aluminum producers must upgrade the present average collection efficiency of 85 percent to an average efficiency of 96 percent to meet the process weight rate standard. For estimating costs to control the sulfur dioxide emissions from copper, lead, and zinc smelting operations, it was assumed that the industry would install acid recovery plants and gas-cleaning equipment where such equipment is considered reasonable as well as feasible. Sulfur dioxide emissions will thereby be reduced from 50,000 ppm to 100,000 ppm to a level of 1000 ppm to 1800 ppm. For aluminum plants, cost estimates were based on the use of either packed towers or electrostatic precipitators on the effluent gases from aluminum reduction pots.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate air pollution control costs for the nonferrous metallurgical industry (primary copper, lead, zinc, and aluminum) consisted of: (a) an evaluation of the various production processes found within the industry(s), (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required levels, including equipment - process size relations. For the sake of clarity, this section will treat aluminum production separately.

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A. Production of Primary Aluminum

The process considered in the production of primary aluminum is the electrolytic reduction of alumina (aluminum oxide) to metallic aluminum. This is accomplished in two primary types of electrolytic reduction cells: the Soderberg cell and the prebaked cell. This study considered only particulate emissions, which are mainly fluorides of sodium and aluminum, alumina dust, and in the case of Soderberg cells, volatilized tarry substances. On the basis of available data [Refs. 1, 2], uncontrolled particulate emission factors for both types of cells were derived and are shown in Table M-1.

Table M-1

UNCONTROLLED PARTICULATE EMISSION FACTORS FOR ELECTROLYTIC REDUCTION CELLS

Cell Type	Uncontrolled Emission Factors (lb/ton aluminum)
Prebaked	60[a]
Soderberg	360[b]

[a] Derived from data found in Reference 2.

[b] Derived from data found in Reference 1.

Precise data on the present level of control were not available. However, on the basis of several references [Refs. 1, 2, and 3], it became apparent that the use of dry mechanical collectors to control coarse particulates in series with open type spray towers to control gaseous fluorides are in common use throughout the industry. Therefore, this system, which is capable of 85 percent particulate removals, was assumed. Required removal efficiencies were calculated for both cell types and are shown in Tables M-2 and M-3.

Table M-2

REQUIRED PARTICULATE REMOVAL EFFICIENCY - PREBAKED CELLS

Annual Capacity (1000 tons of Aluminum)	Removal Efficiency Required (percent)
70	93.2
105	94.4
140	95.6
175	96.3
210	96.8
245	97.1
280	97.5

Data compiled from Reference 1.

Table M-3

REQUIRED PARTICULATE REMOVAL EFFICIENCY - SODERBERG POTS

Annual Capacity (1000 tons of Aluminum)	Removal Efficiency Required (percent)
70	98.9
105	99.1
140	99.2
175	99.3
210	99.4
245	99.5
280	99.6

Data compiled from Reference 2.

Notable in the aluminum industry are the copious quantities of process off-gases. These result from the need of ventilating entire potline buildings.[1/] The relationships between gas volume and process size were calculated from data available in several references [Refs. 1, 2, 3, and 4]. These are presented in Tables M-4 and M-5.

Table M-4

CAPACITY AND GAS VOLUME - PREBAKED CELLS

Annual Capacity (1000 tons of Aluminum)	Total Gas Volume (cfm)
70	5×10^6
105	7.5×10^6
140	10×10^6
175	12.5×10^6
210	15×10^6
245	17.5×10^6
280	20×10^6

Table M-5

CAPACITY AND GAS VOLUME - SODERBERG CELLS

Annual Capacity (1000 tons of Aluminum)	Total Gas Volume[a] (cfm)
70	8×10^6
105	12×10^6
140	16×10^6
175	20×10^6
210	24×10^6
245	28×10^6
280	32×10^6

[a] For all cells.

[1/] A potline is a series of aluminum reduction cells called pots.

To achieve the required removal efficiencies, the following types of control equipment in series with existing equipment were chosen on the basis of available information: packed towers for prebaked cells and electrostatic precipitators for Soderberg cells. (Process size - equipment cost relationships are discussed in Section IV.)

B. Primary Smelting of Copper, Lead and Zinc

Obtaining and analyzing air pollution control costs for these primary metal industries was limited to the primary smelting processes only. The refining steps were not considered a problem from the point of view of particulate or SO_2 emissions [Ref. 1]. In addition, particulate emissions resulting from primary smelting operations are consistently controlled to levels in excess of 95 percent. Therefore, the resulting cost analysis focused on the control of SO_2 from primary smelting operations. The primary metallurgical processes analyzed in the smelting operations for each metal are shown in Table M-6.

Table M-6

METALLURGICAL PROCESSES FOR COPPER, LEAD, AND ZINC

Metal	Primary Smelting Processes[a]
Copper	Roaster-reverberatory furnace - converter or Reverberatory furnace-converter
Lead	Sintering - blast furnace[b]
Zinc	Roaster[c]

[a] The analysis was limited to these process systems because they represent the systems present in the study areas. There are other possible configurations for each metal.

[b] SO_2 emissions negligible.

[c] Followed by a usually well controlled electrolytic reduction step.

Based upon data developed in the McKee report [Ref. 5], a model plant approach was adopted as the basis of the cost analyses. The model plants are presented in Table M-7.

Table M-7

PRIMARY SMELTING - MODEL PLANTS

Metal	Processes	Model Plants	
		Gas Volume (1000 scfm)	SO_2 Concentration (percent by volume)
Copper	Roaster & converter	75	5
	Converter alone	50	8[a]
	Reverberatory furnace	100	1 or 2[b]
	Combined gas stream after acid plant	175	0.8[c] or 1.4[c]
Lead	Sinter machine	50	5.
Zinc	Roaster	50	8

[a] This gas stream is representative when smelting operation includes only a reverberatory furnace and converter.

[b] One percent when preceded by roaster; two percent when furnace is the initial smelting step.

[c] Acid plant tail-gas plus reverberatory furnace off-gas.

The use of these models requires further explanation. Information was obtained on the presence or absence of acid conversion facilities at each plant location in the study areas [Ref. 6]. Therefore, the cost estimating methodology, which is fully discussed in the next section, was based upon the addition of acid conversion plants where none now exist plus wet lime scrubbing systems, where reasonable, to reduce SO_2 concentration to economically feasible limits; the 500 ppm standard cannot be reasonably met.

Copper smelting plants within the study areas use either reverberatory furnace-converter smelting systems or roaster-reverberatory furnace-converter systems. With the first process, only converter off-gases are amenable to acid plant conversion of SO_2[2] and the resulting combined gas stream from the reverberatory furnace and acid plant tail-gas must be further treated in a wet lime scrubber. In the second copper smelting configuration, combined roaster and converter off-gases are sent to an acid conversion plant and the combined tail gas - reverberatory furnace off-gas stream must then be sent to the secondary scrubber.

In lead smelting operations, only sinter machine off-gases must be treated in an acid plant. The blast furnace operations which take place in series with the sintering step emits negligible SO_2. It is not considered reasonable to further treat the acid plant tail-gas.[3]

In zinc smelting operations, only the roasting process results in serious SO_2 emissions. The off-gases should be treated in an acid conversion plant to obtain effective control. Again, it is not considered reasonable to further treat the acid plant tail-gas.

IV. CONTROL COST FOR 1967 BASE YEAR

A. Methodology

Due to the limited number of primary smelters and aluminum plants within the 100 metropolitan areas, cost estimates were developed for each.

Four of the five aluminum reduction plants are prebaked cell operations and one is a Soderberg cell operation. For the prebaked operations, unit costs of packed tower systems were available from the Poly Con Corporation. Total installation costs were determined by multiplying the equipment cost by a factor of 2 [Ref. 7]. The equipment and operating costs curves are presented in Figures M-1 and M-2.

For the one Soderberg operation, the equipment cost for electrostatic precipitators were obtained from Figure M-3. However, annual operating and maintenance costs had to be computed using the two empirical relations given in Reference 7.

Costs for copper, lead, and zinc smelters were based on the costs for building and operating acid conversion plants in locations where there were none and for building and operating wet lime scrubbing systems where applicable. Capital and operating cost relationships for these

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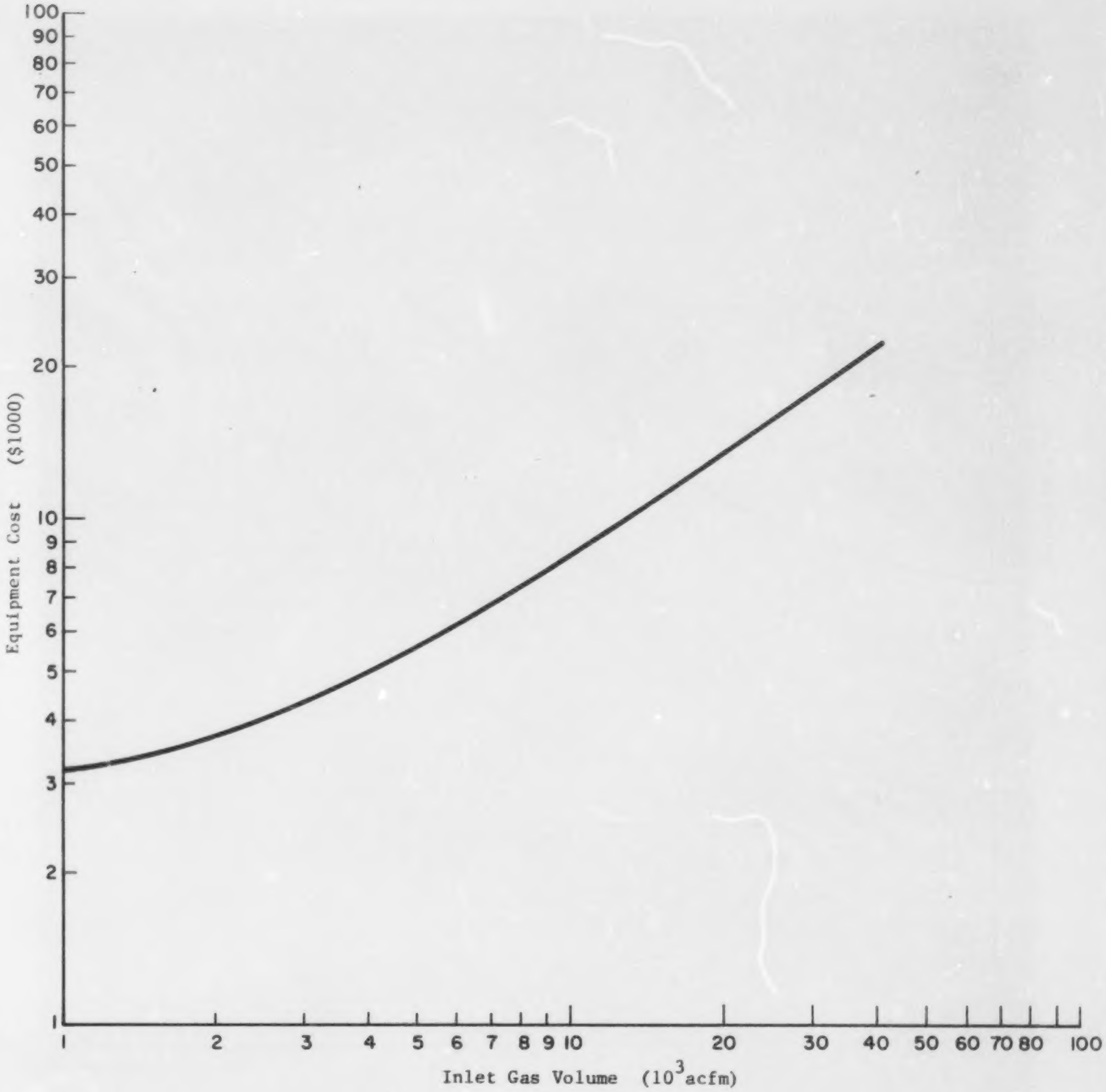
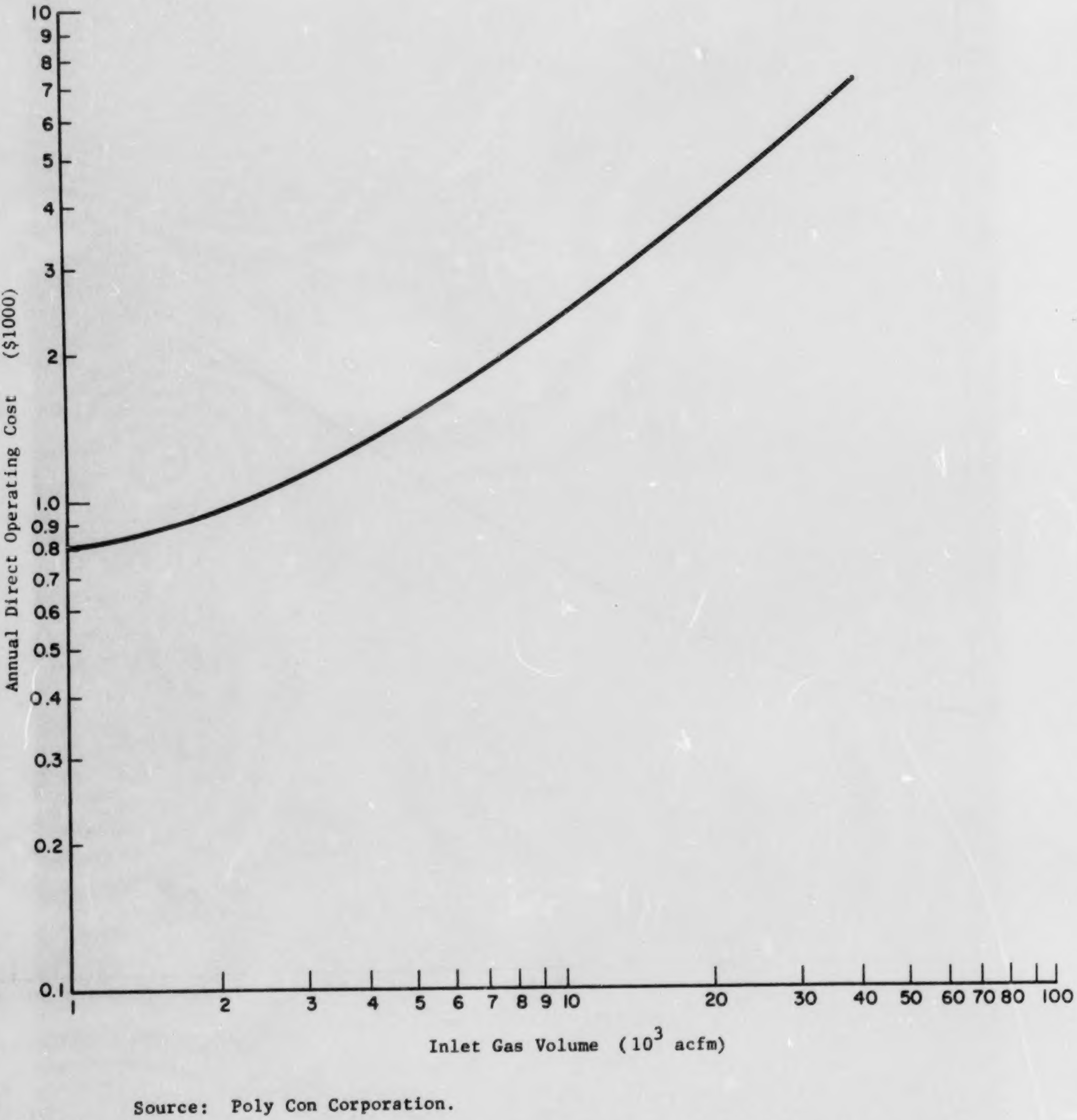
[2] The criterion is 3 percent or greater SO_2 concentration (see Table M-7).

[3] The resultant SO_2 concentration should be less than 0.1 percent.



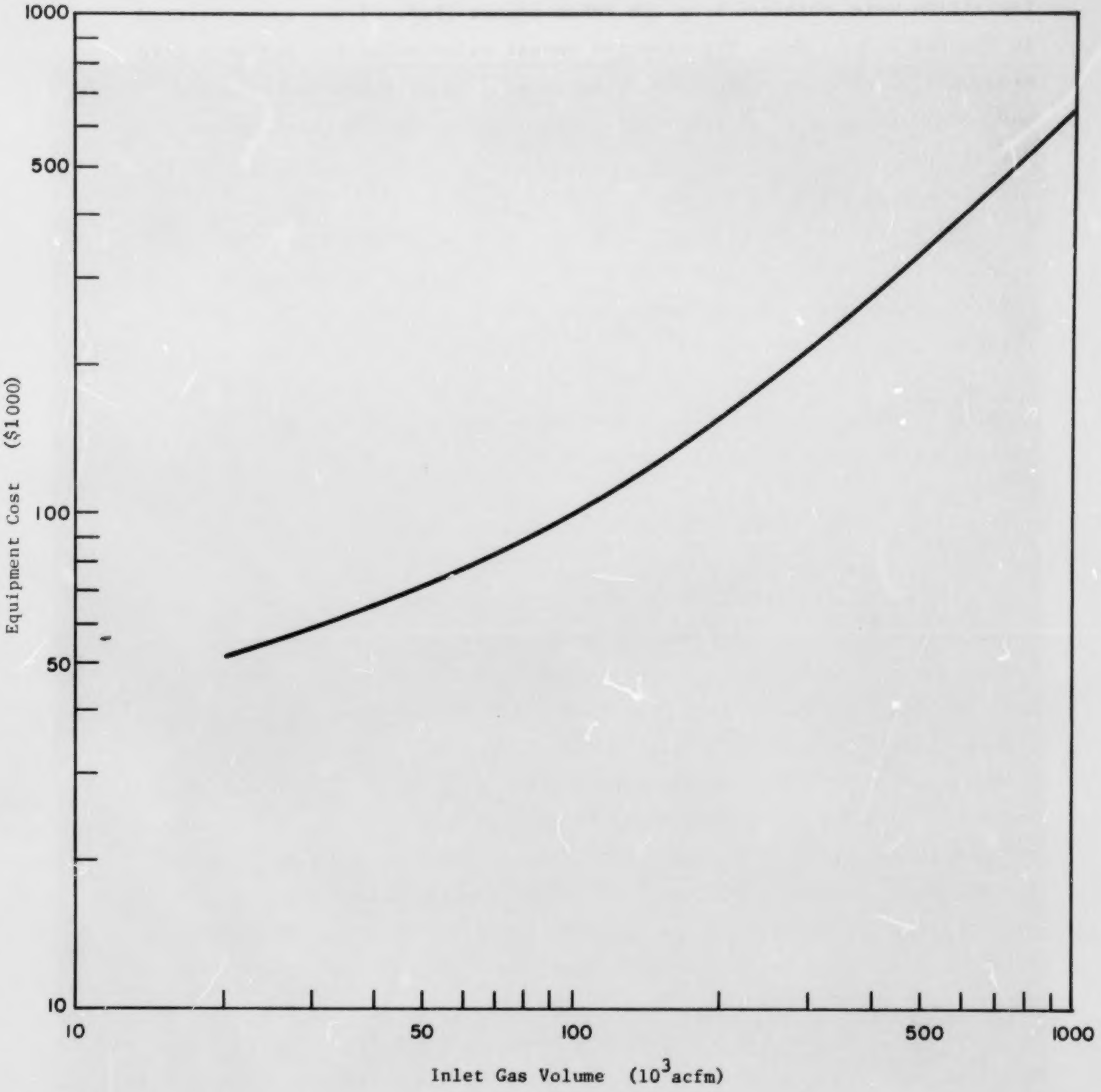
Source: Poly Con Corporation.

Fig. M-1. Equipment Cost for Packed Towers.



Source: Poly Con Corporation.

Fig. M-2. Annual Direct Operating Cost for Packed Towers.



Source: Edmisten, N. G. and F. L. Bunyard, "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources." Presented at the annual meeting of the Air Pollution Control Association, New York, June 1969.

Fig. M-3. Equipment Cost for High-voltage Electrostatic Precipitators.

facilities were obtained from the McKee report [Ref. 5] and are presented in Figures M-3 to M-8. The expected annual sales value for sulfuric acid produced in the conversion plants, assuming sale of the acid, exceeded the total annual cost of operating, maintaining, and depreciating the facilities.

B. Estimated Costs

The resulting costs, which take into account existing controls, were totalled for the 100 metropolitan areas and are shown in Table M-8. Control costs would average approximately $6.91 per unit of capacity when the plan is fully implemented.

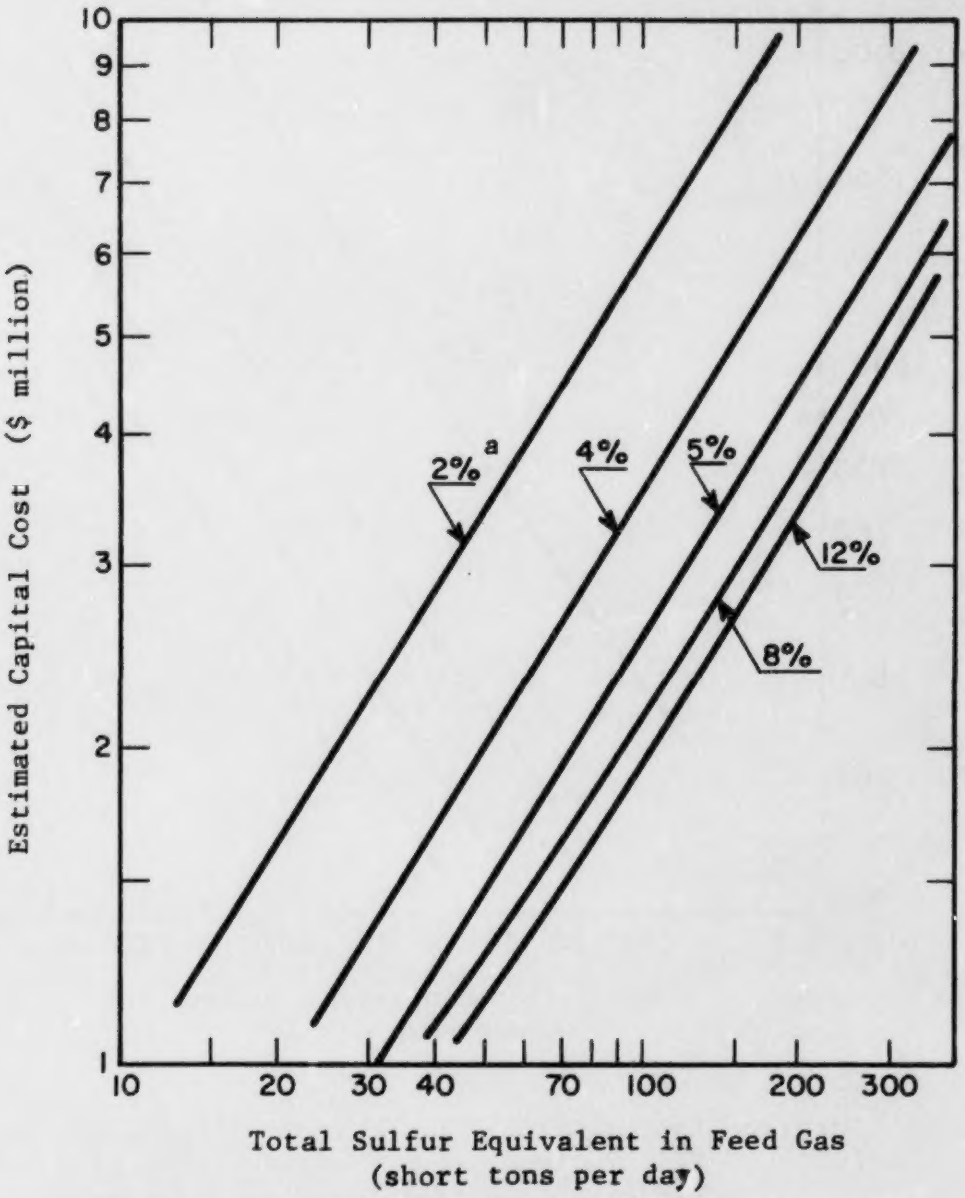
The emission of particulates and sulfur dioxide would be reduced from 22 thousand tons and 144 thousand tons respectively in 1967 to 15 thousand tons and 4 thousand tons by 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for increased capacity in the industry beyond the base year 1967. The projected growth costs were based upon the ultimate control levels of 98.8 percent for sulfur dioxide emissions in the copper, lead, and zinc industries and 96.0 percent for particulates in the aluminum industry. The calculations consisted of multiplying the total 1967 investment and annual control costs by percent growth of the additional capacity

Estimates of 9, 3, 1, and 0 percent were used for the growth of the aluminum, copper, lead, and zinc industries respectively in the 100 metropolitan areas [Refs. 8 and 9]. The capacity estimates, derived from the production estimates, were based upon achieving a capacity utilization rate of 90 percent by FY 1975.

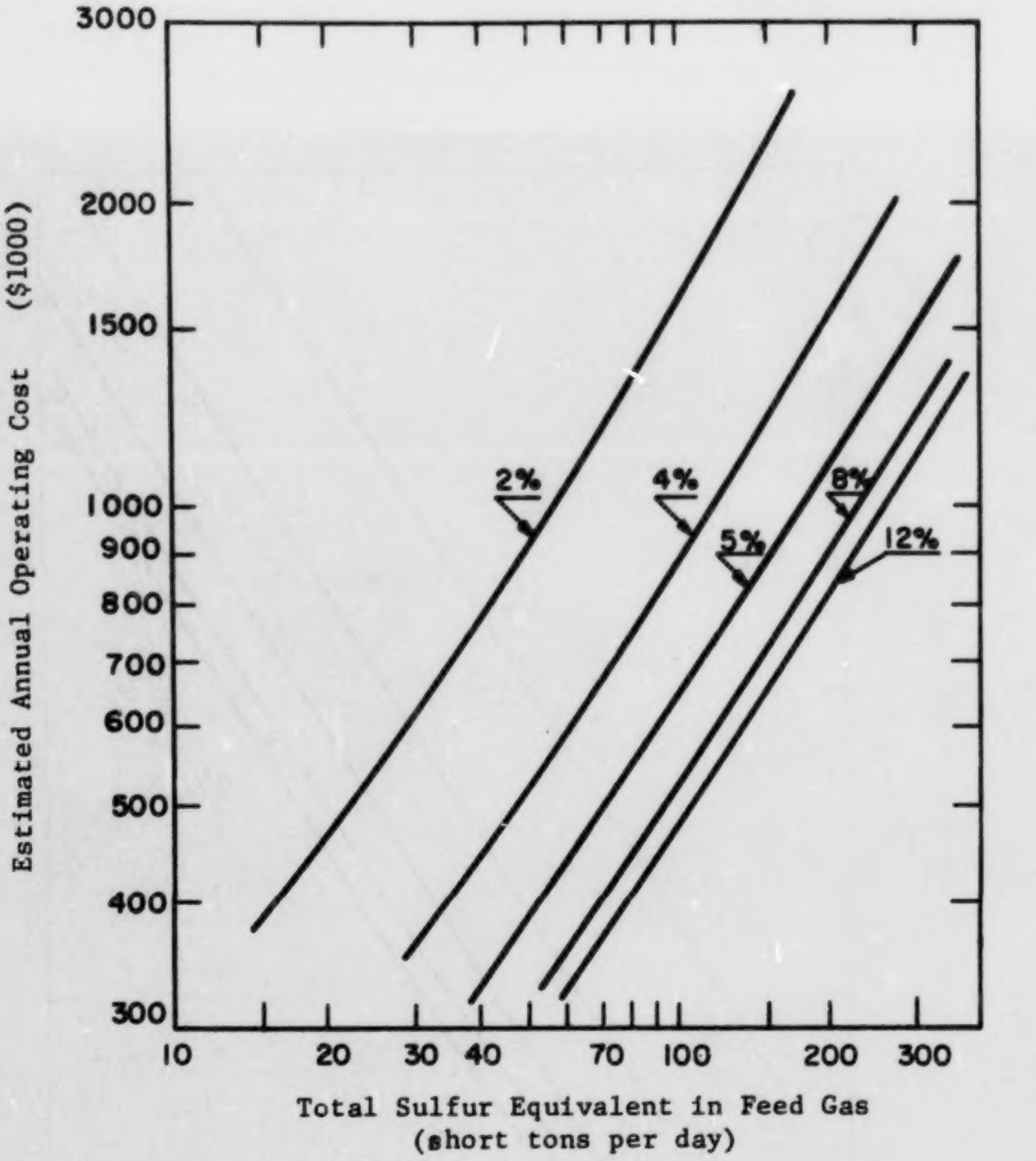
The costs of controlling the additional capacity are shown in Table M-9. Costs in each year reflect immediate control of the incremental capacity at the ultimate control levels. In the 100 metropolitan areas, without the act in effect, emissions from the 1967 capacity plus the additional capacity would reach 29 thousand tons of particulates and 175 thousand tons of SO_2. With the act in effect, emissions of 17 thousand tons of particulates and less than 5 thousand tons of SO_2 would result.



[a] Percent sulfur dioxide in feed gas.

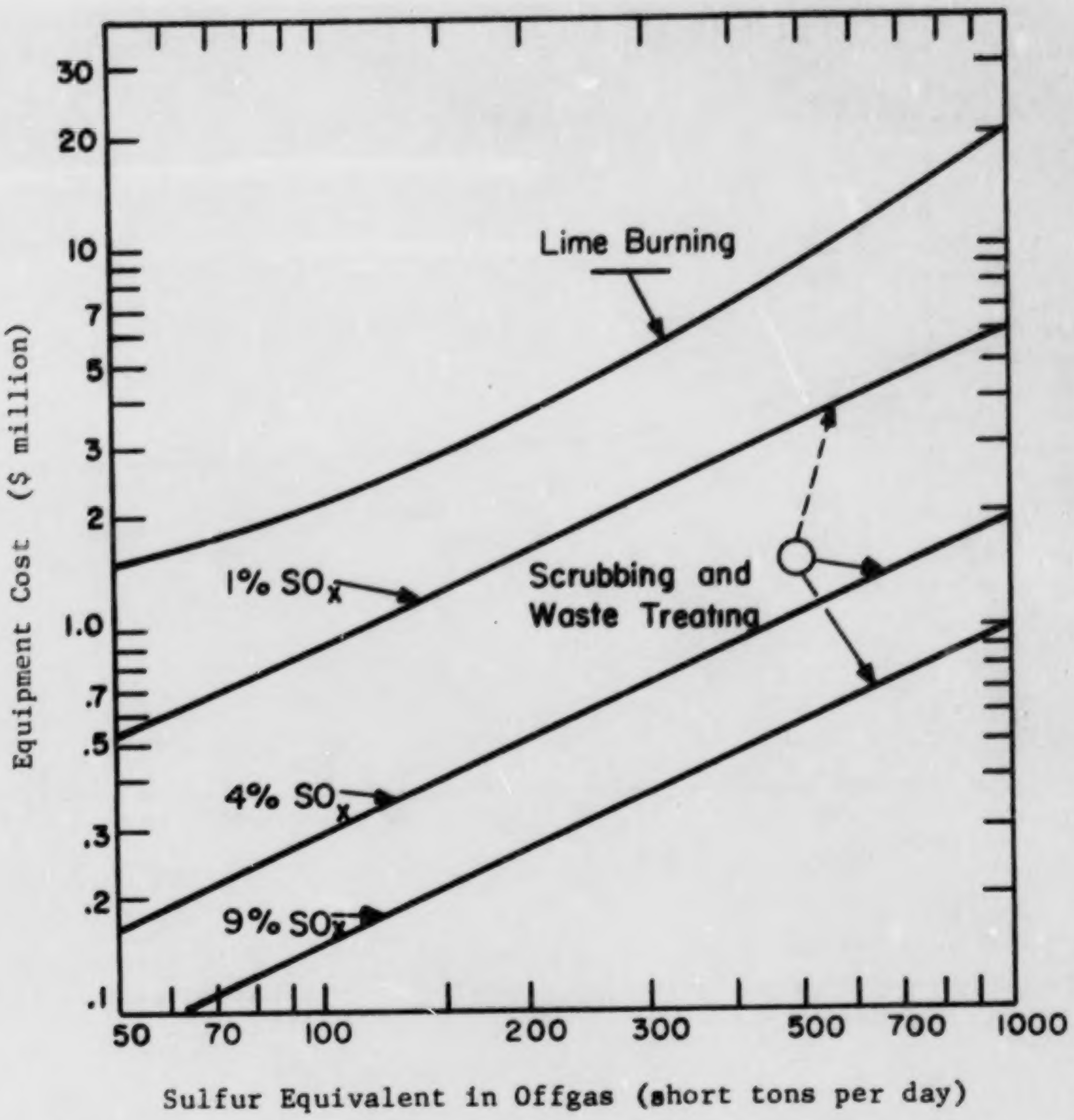
Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. M-4. Capital Costs for the Contact Sulfuric Acid Process.



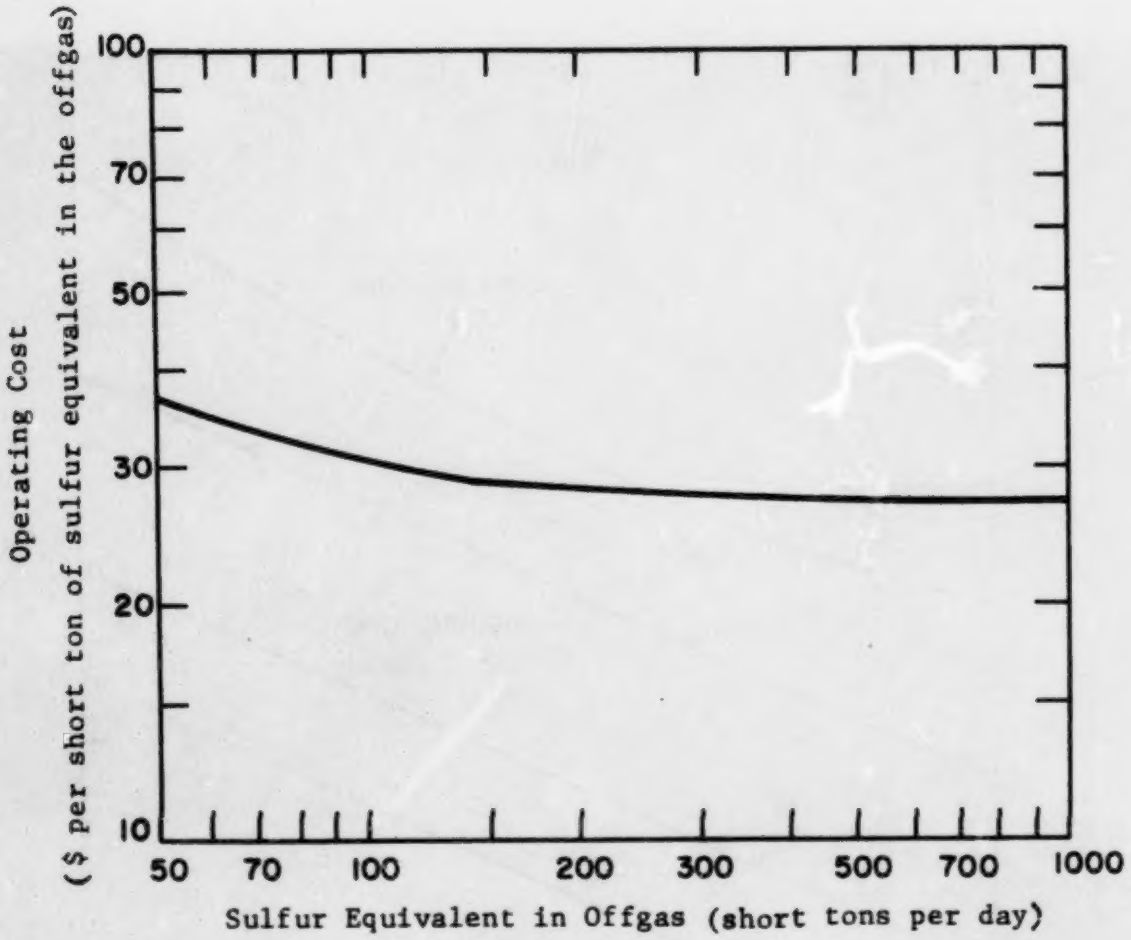
Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. M-5. Annual Operating Costs for Contact Sulfuric Acid Process.



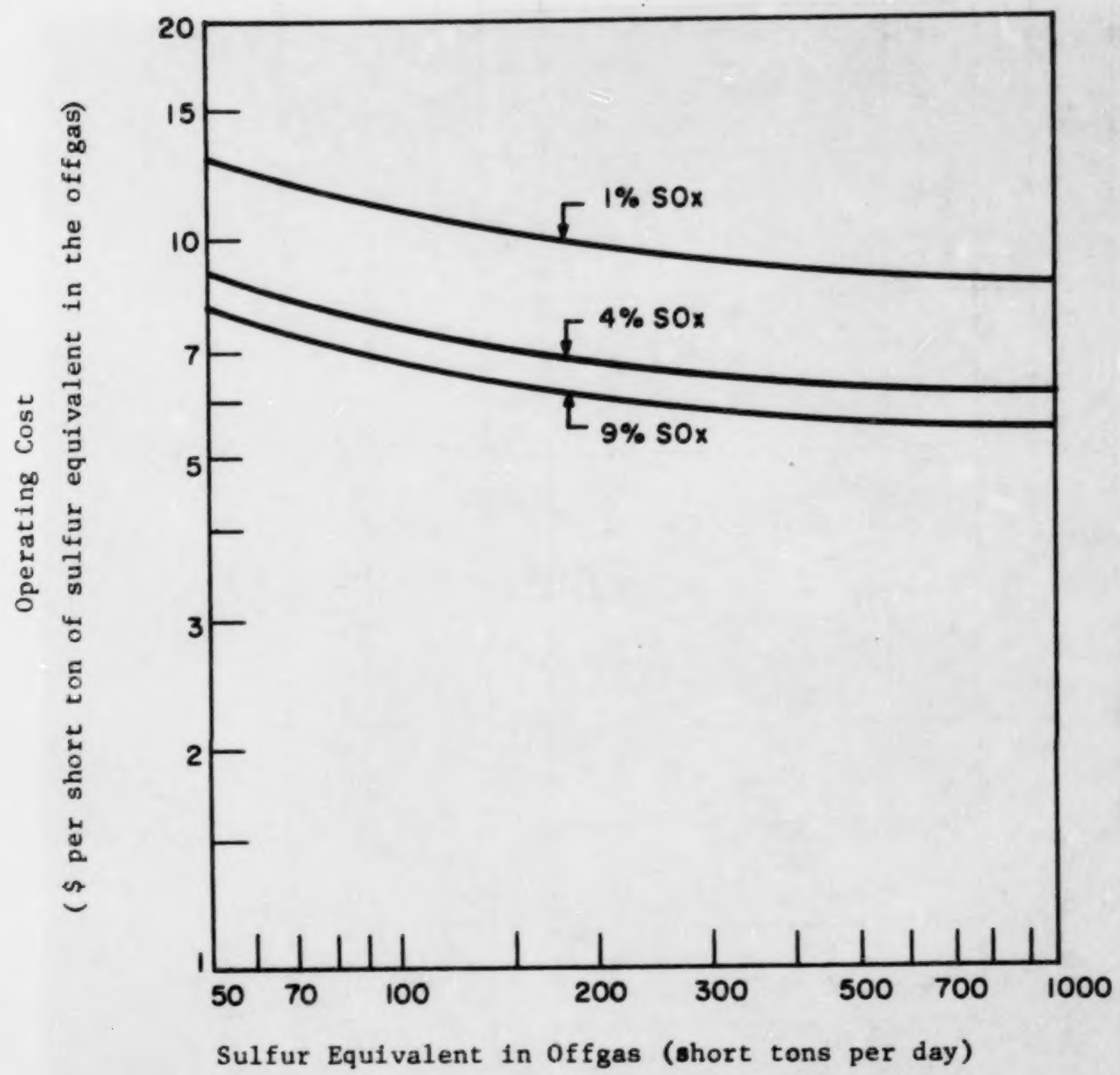
Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. M-6. Equipment Costs for Lime Wet-Scrubbing Process.



Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. M-7. Operating Costs for the Lime-Burning Section of the Lime Wet-Scrubbing Process.



Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. M-8. Operating Costs - Scrubbing and Waste-Treating Section of Lime Wet-Scrubbing Process at 100% of Capacity.

Table M-8

PRIMARY NONFERROUS METALLURGICAL PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part[c]	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	12/10	144	--	--	95.0/ 85.0	49.0	--	--						
FY71	12/10	144	--	--	95.0/ 85.1	49.2	--	--	0.0	0.0	0.0	0.0	0.0	0.0
FY72	12/9	125	--	--	95.0/ 86.2	55.9	--	--	5.1	10.2	12.2	1.8	3.6	4.3
FY73	12/7	71	--	--	95.0/ 90.2	74.8	--	--	13.6	27.1	32.5	6.6	13.1	15.7
FY74	12/4	20	--	--	95.0/ 94.4	92.9	--	--	11.8	23.7	28.4	10.6	21.2	25.4
FY75	12/3	4	--	--	95.0/ 96.0	98.8	--	--	3.3	6.6	7.9	11.8	23.5	28.2
Total -									33.8	67.6	81.0	30.8	61.4	73.6

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

[c] Emission levels and emission control levels are shown for copper, lead, and zinc plants combined and for aluminum plants separately; a slash mark separates the two estimates in each case.

Table M-9

PRIMARY NONFERROUS METALLURGICAL PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a] (100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr)	ADDITIONAL PRODUCTION (thousand tons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	529	245	1	<1	--	--	1.1	2.2	2.6	0.3	0.7	0.8
FY72	662	312	1	<1	--	--	1.6	3.2	3.9	0.9	1.8	2.1
FY73	794	379	1	<1	--	--	1.8	3.6	4.3	1.5	3.0	3.6
FY74	927	445	1	<1	--	--	1.3	2.7	3.2	1.9	3.9	4.6
FY75	1,060	512	2	<1	--	--	1.0	2.0	2.4	2.2	4.5	5.5
Totals -							6.8	13.7	16.4	6.8	13.9	16.6

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix N

Sulfuric Acid Industry
(SIC No. 2819)

Appendix N

Sulfuric Acid Industry

I. INTRODUCTION

Sulfuric acid is a strong, economically priced, inorganic acid that is used in the manufacture of fertilizer and tin plate, in the purification of petroleum, and in the dyeing of fabrics as well as in many other industrial processes. Most sulfuric acid is produced by the contact process which involves burning sulfur or pyrite to form sulfur dioxide that is catalyzed to sulfur trioxide and then absorbed in weak acid. Sulfur dioxide that remains unconverted and acid mist which escapes from the acid absorption tower are the major pollutant emissions.

Of the 212 sulfuric acid plants in the Nation, there are 102 contact process plants within the 100 metropolitan areas. The small number of lead chamber process plants in the United States and the 100 areas produce less than five percent of the acid. For the Nation, capacity totalled 38.7 million tons, production amounted to 28.8 million tons, and value of shipments was $0.3 billion. For the 102 contact plants within the 100 metropolitan areas, capacity totalled 24.4 million tons with production amounting to 18.2 million tons and a value of shipments of $0.2 billion. For the Nation, emissions amounted to 60 thousand tons of acid mist particulates and 750 thousand tons of SO_2; for the 100 metropolitan areas, emissions amounted to 40 thousand tons and 480 thousand tons, respectively.

II. CONTROL OF EMISSIONS

To comply with the process weight rate regulation for particulate emissions and the 500 parts per million (ppm) standard for sulfur oxides, sulfuric acid producers must increase the average collection efficiency of particulates from the present 46 percent to about 67 percent; sulfur oxides, which are not presently controlled, must be increased from 0 to 86 percent.

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To obtain effective control, it was assumed that the typical plant would require the installation of a second absorption tower to decrease emissions of sulfur dioxide and the emplacement of gas-cleaning equipment, such as a demister, to lower particulate emission levels.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate control costs for the sulfuric acid industry consisted of: (a) an evaluation of the various production processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve required levels, including equipment cost - process size relationships.

The rate of emission of tail-gas from a contact sulfuric acid plant is determined by the concentration of SO_2 in the feed stream to the SO_2-to-SO_3 convertor; this concentration is subject to process control. Many plants take enough air into their sulfur burner to provide adequate excess oxygen for conversion, others add so-called "dilution air" after burning but prior to one or more stages of the convertor. To maintain plant thermal balance, it is necessary for the SO_2 concentration to be in excess of about 3 percent. As the SO_2 concentration is increased, stack losses of unconverted SO_2 also increase. Most plants vary the SO_2 concentration in order to vary production, but avoid concentrations causing conversion efficiency to fall below about 96 percent.

It was assumed that 96 percent conversion is obtained with an 8 percent SO_2 concentration to the convertor and that the actual tail-gas rate is thus about 74 acfm (at 150° F) per ton-per-day (tpd) plant capacity.

The concentration of SO_2 in the tail-gas from a contact sulfuric acid plant operating at 8 percent SO_2 concentration to the convertor and 96 percent conversion efficiency is fixed at about 3500 ppm. This figure was assumed to represent average operations for the industry and agrees with literature, industrial, and NAPCA sources as representative of present-day operations. The assumed SO_2 standard of 500 ppm thus requires an 86-percent reduction in the present average emissions.

With the exception of oleum production (sulfuric acid containing excess SO_3), acid mist emissions from contact sulfuric acid plants are less subject to process control variation than are SO_2 emissions. Acid mists arise from two independent sources, moisture-SO_3 reactions within and outside of the process equipment and liquid sulfuric acid entrainment in exhaust from the SO_3 absorber. The moisture-SO_3 reactions include reactions of SO_3 with residual moisture in the dried process air, moisture arising from the oxidation of hydrocarbon impurities in the sulfur, and atmospheric moisture that contacts the tail gas exiting the stack. The moisture-SO_3 sources depend on the operation of the drier and whether or not oleum is being manufactured. Fine acid or SO_3 mists are formed after the convertor when either moisture reacts with SO_3 or the SO_3 dew-point (50° C = 122° F) is reached. Both types of mists pass through the absorber with little removal and thence through the stack. If SO_3 mists are emitted, they react with atmospheric moisture to produce acid mists.

For this report, a value of 16 mg mist per scf of tail-gas was assumed. This value is somewhat higher than the average reported in Reference 1 but is in line with the more recent data reported in Reference 2. The particulate emission standards are the process weight rate standards. Because combustion air is excluded, the weight rate factor is $(32+18)/98 = 0.51$, i.e., 0.51 pounds of raw materials yield 1.00 pound of product. The required efficiency for particulate control ranges from 43 percent for a 50 tpd plant to 93 percent for a 5000 tpd plant.

The basis for control of SO_2 emissions was that of improving process yield, but because very high (about 99.5 percent) overall SO_2-to-SO_3 conversions were required to meet the 500 ppm standard, cost estimating was limited to the double absorption method. The basis chosen for estimating the cost of acid mist control was utilization of glass-fiber mist eliminators capable of removing 100 percent of particles greater than 3 microns and about 80 percent of particles less than 1/2 micron. Reference 1 gives limited data indicating that mist particles may be assumed to be such that adequate control will result. These devices were assumed to operate with 6" to 8" w.g. pressure drop.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Sulfuric acid plants were reported by location and capacity [Ref. 3]. The controls selected were second absorption towers in the acid-making process and additional acid mist eliminators in the exhaust streams, where necessary. Some plants need another catalyst bed, however, such would be an investment in production equipment.

Available information led to the assumpton that 35 of the plants within the metropolitan areas already control mists adequately. For lack of more complete information, mist eliminators were assumed to be in use at all plants in Los Angeles and at the 26 largest plants in other areas.

Costs were calculated assuming one process stream per plant, since no plant was reported to have a capacity larger than the known maximum process stream size. The cost of adding a second tower was included in the estimated control cost, but the cost of another catalyst bed was assumed to be compensated for by the increased production efficiency. Cost parameters for a second absorption tower were based on data from Chemical Engineering Progress [Ref. 4], which gives costs for a new plant of 1000 tons per day production using either single or double absorption. The difference in costs was multiplied by 1.3 to allow for modification of existing equipment, and then scaled to other plant sizes based on the cost being proportional to capacity to the 0.6 power. Cost parameters for mist eliminators were based on data from the Monsanto Chemical Company (Brinks Mist Eliminators). Costs were calculated for each plant by capacity and then aggregated for the 100 metropolitan areas. These costs are presented in Tables N-1 and N-2.

Table N-1

SULFURIC ACID EMISSION CONTROL COSTS: DOUBLE ABSORPTION

Plant Size (100% H_2SO_4, tons/day)	Costs ($1000)	
	Investment	Annual
50	81	18.9
100	123	28.9
200	186	44.7
500	323	81.1
1000	505	139.0
5000	1420	444.0

Table N-2

SULFURIC ACID EMISSION CONTROL COSTS: MIST ELIMINATOR[a]

Plant Size (100% H_2SO_4, tons/day)	Costs ($1000)	
	Investment	Annual
50	4.5	0.9
100	9.5	1.9
200	19.5	3.9
500	43.8	8.8
1000	82.5	16.5
5000	375.0	75.0

[a] Brink Mist Eliminator, Type H-V or S-C.

B. Estimated Control Costs

The resulting costs, which include credits for additional sulfuric acid recovery, were totalled for the 100 metropolitan areas and are shown in Table N-3. Annual control costs would average approximately $0.09 per ton of sulfuric acid capacity when the plan is fully implemented. This rather minimal cost can be accounted for by the fact that double contact units and, to a lesser extent, fiber glass demisters lead to an increased yield of sulfuric acid from raw materials.

The emission of particulates would be reduced from over 40 thousand tons in 1967 to approximately 24 thousand tons by 1975, while sulfur dioxide emissions would be reduced from 480 thousand to 56 thousand tons. The investment cost for this level of control would total $32.6 million with an annual cost of $2.2 million by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for additional capacity in the sulfuric acid industry beyond the base year of 1967. The projected control costs for additional capacity were based on the expected ultimate control level of 86.0 percent and 67.0 percent for sulfur dioxide and particulates, respectively. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An average annual growth rate of 4.5 percent was used to estimate increases from 1967 to FY 1975 [Ref. 1]. The capacity estimates were derived by assuming production would achieve 90 percent utilization of capacity by FY 1975. The costs of controlling the additional capacity are shown in

Table N-3

SULFURIC ACID PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	40	480	--	--	45.7	0.0	--	--						
FY71	39	381	--	--	46.8	7.7	--	--	1.4	1.7	2.1	0.1	0.1	0.1
FY72	35	293	--	--	52.2	26.6	--	--	6.4	8.0	9.6	0.4	0.6	0.8
FY73	29	160	--	--	60.5	60.1	--	--	9.9	12.4	14.8	1.0	1.4	1.9
FY74	25	78	--	--	65.6	80.4	--	--	6.4	8.0	9.6	1.3	1.9	2.5
FY75	24	56	--	--	67.0	86.0	--	--	2.0	2.5	3.1	1.5	2.2	2.8
Total -									26.1	32.6	39.2	4.3	6.2	8.1

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table N-4. As shown, costs reflect immediate control of the incremental capacity at the ultimate control levels. By 1975, without the act in effect, emissions in the 100 areas from 1967 base sources plus the additional sources would reach 55 thousand tons of particulates and 561 thousand tons of SO_2. With the act in effect, emissions would be reduced to 32 thousand tons and 78 thousand tons, respectively.

Table N-4

SULFURIC ACID PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a] (100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr)	ADDITIONAL PRODUCTION (thousand tons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	1219	2859	3	10	--	--	0.5	0.6	0.8	0.1	0.1	0.1
FY72	1567	3676	5	13	--	--	0.7	0.9	1.1	0.1	0.1	0.1
FY73	1915	4493	6	16	--	--	0.9	1.1	1.3	0.1	0.2	0.1
FY74	2263	5310	7	19	--	--	0.7	0.9	1.1	0.1	0.2	0.3
FY75	2611	6127	8	22	--	--	0.5	0.7	0.8	0.2	0.2	0.3
Totals -							3.3	4.2	5.1	0.6	0.8	.9

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix O

Phosphate Fertilizer Industry
(SIC No. 2871)

Appendix O

Phosphate Fertilizer Industry

I. INTRODUCTION

The segment of the phosphate fertilizer industry studied produces phosphoric acid by the wet acid process, and using this production intermediate, produces various phosphate fertilizers.[1/] Wet process phosphoric acid is manufactured by treating phosphorus-bearing rock with sulfuric acid, and fertilizer is produced by reacting the phosphoric acid with other chemicals. In some instances, only phosphoric acid is produced at a plant.

Particulates released from rocks during the acid-making process are the primary concern of this report; however, particulates (mostly fluorides) emitted from fertilizer handling operations in sheds where fertilizer is stored for curing also need control. In 1967, there were 171 phosphoric acid and/or phosphate fertilizer production sources in the United States with combined acid and fertilizer capacity of 22.9 million tons (of equivalent P_2O_5) with a production of 8.5 million tons. Within the 100 metropolitan areas, there were 19 such sources with a capacity of 3.5 million tons and producing 2.3 million tons. Value of shipments amounted to \$1.2 billion and \$0.4 billion for the United States and the 100 areas respectively. Twenty thousand tons of particulates were emitted in the United States in 1967; 11 thousand tons were attributed to the 100 areas.

II. CONTROL OF EMISSIONS

Although practically the entire industry is presently exercising some control of gaseous and particulate fluoride emissions, fluoride and nonfluoride particulates are still being emitted. These emissions, in the case of large plants, exceed the process weight rate regulation adopted for this study. Installation of secondary gas-cleaning systems on the gas stacks of manufac-

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[1/] Including normal superphosphate (NSP), diammonium phosphate (DAP) and more recently triple superphosphate (TSP).

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turing plants and on curing shed exhaust is assumed for reducing the total amount of particulates to comply with the standard. Emissions in the 100 areas can be reduced from 11 thousand tons per year to 4 thousand tons by FY 1975 with secondary emission control equipment.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate control costs for the phosphate fertilizer industry consisted of: (a) an evaluation of the various production processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required levels, including equipment cost - process size relationships.

The rate of tail gas emission from a phosphate fertilizer plant is a function of plant capacity, the processes included, and the degree of ventilation provided. Major volumes of gas generation are associated with (a) rock beneficiation and calcining, (b) wet acid and subsequent phosphate fertilizer processing, and (c) curing for run of pile TSP. Due to the magnitudes of the flows and the nature of the processes, the following assumptions were made: processes (a) and (b) may be treated at one tail-gas stack and together they produce two-thirds of the overall gas flow; process (c) is treated at a separate stack and produces the remainder of the overall gas flow. The overall rate was assumed (from Reference 1 and industrial sources) to be about 750 acfm/ton per day capacity (as P_2O_5) at 150° F.

Phosphate fertilizer production is a major source of fluoride and particulate emissions. This study excludes gaseous fluorides but includes both fluoride and nonfluoride particulates. Because of the extreme toxicity of fluoride emissions, all plants were assumed to have at least primary gas-cleaning equipment and were assumed to be emitting 0.03 to 0.10 grains total particulate matter/acf tail-gas [Ref. 1].

The emission standard assumed was the process weight rate type. The weight rate factor is the sum of the tons of mined rock per hour plus sulfuric acid per hour introduced into the process. The relationship between raw materials and product is 6.2, i.e., 6.2 pounds of raw materials yield 1.0 pound of product [Ref. 2]. The required control efficiency varies from 0 percent for 50 to 100 ton-per-day plants to 80 percent for 1000 ton-per-day plants.

The basis for control of particulate emissions was secondary or tail-gas scrubbers. Curing sheds were assumed to provide one-third of the overall gas flow and to require 10" w.g. at the scrubbers. The remaining two-thirds of overall gas flow was assumed to require 15" w.g. at the scrubbers. Scrubbers assumed were venturi-stack type of stainless steel construction requiring an installed cost equal to 300 percent of the equipment cost. Systems rated at up to 500 tons per day of P_2O_5 equivalent were assumed single train (two tail-gas stacks, one for the acid-making train and one for the shed) and those larger were assumed to consist of multiples of the 500 ton-per-day units.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Plants making basic phosphate fertilizer material were included in the analysis. In 1967, some of the 19 plants in the 100 areas also produced phosphoric acid by the wet process. Data on plant location, types of processes, and capacity were obtained from industrial publications [Refs. 3 and 4]. Data were obtained from private sources on gas flows and other parameters such as number of exhaust stacks [Ref. 5]. Unit costs for the wet scrubbers needed were also obtained [Ref. 5].

Costs were estimated on the assumption that the largest single stream (one stack) corresponded to 500 tons per day (P_2O_5 equivalent) acid train.

Larger plants were assumed to be linear multiples of 500 tons per day. However, additional stacks were not assumed for the curing sheds of larger plants. Industry practice of material control is sufficient to control air pollution for plants making less than 150 tons per day. See Table 0-1 for the individual plant control cost estimates.

Table 0-1

PRIMARY PHOSPHATE FERTILIZER CONTROL COSTS

Plant Capacity (1000 tons/year)	Investment Cost ($1000)	Annual Cost ($1000)
3.12[a]	32.0	11.0
15.6[a]	80.0	30.0
31.2[a]	120.0	50.0
47.0[a]	181.0	72.0
62.4	240.0	110.0
156.0	530.0	225.0
312.0	1060.0	450.0
624.0	2120.0	900.0

[a] Plants of up to 47.0 thousand tons/year capacity assumed to have adequate control. Costs are shown for reference purposes only.

Plants that need additional control would likely use low or medium energy wet scrubbers; these were the bases of individual plant costs. It was assumed that plants operate 312 days per year.

B. Estimated Control Costs

The resulting costs, which take into account existing controls, were totalled for the 100 metropolitan areas; these are shown in Table 0-2. Annual control costs would average approximately $1.57 per ton of annual capacity when the plan is fully implemented. The total investment costs would reach $4.8 million with an ultimate annual cost of $2.0 million.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing production (Section IV) but also for anticipated increased production in the phosphate fertilizer industry. The projected growth-related costs were calculated on the basis of the ultimate particulate control level of 99.0 percent.

An average annual production growth rate of 6.5 percent was chosen based on available information [Ref. 6]. Although the phosphate fertilizer industry is in the process of shutting down portions of its 1967 capacity, the newly added capacity and production can probably be explained by three trends. These are: (a) the trend to larger more efficient operations, (b) the trend away from the use of NSP toward the use of TSP, and (c) the trend toward the use of higher-yield DAP. In 1967, there was some surplus capacity; however, new capacity will be required to satisfy the need by 1975.

As shown in Table 0-3, the costs in each year reflect immediate control of the incremental capacity at the ultimate control efficiency. By 1975, without the act in effect, emissions in the 100 areas from both 1967 base capacity and the additional growth would amount to 16 thousand tons of particulates; with the act in effect, emissions would amount to about 6 thousand tons.

Table 0-2

PHOSPHATE FERTILIZER PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	11	--	--	--	97.0	--	--	--						
FY71	11	--	--	--	97.1	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
FY72	10	--	--	--	97.3	--	--	--	0.4	0.6	0.8	0.1	0.2	0.3
FY73	7	--	--	--	98.0	--	--	--	1.2	1.8	2.5	0.6	1.0	1.4
FY74	5	--	--	--	98.7	--	--	--	1.1	1.8	2.5	1.1	1.7	2.4
FY75	4	--	--	--	99.0	--	--	--	0.4	0.6	0.9	1.3	2.0	2.7
Total -									3.1	4.8	6.7	3.1	4.9	6.8

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table 0-3

PHOSPHATE FERTILIZER PLANTS

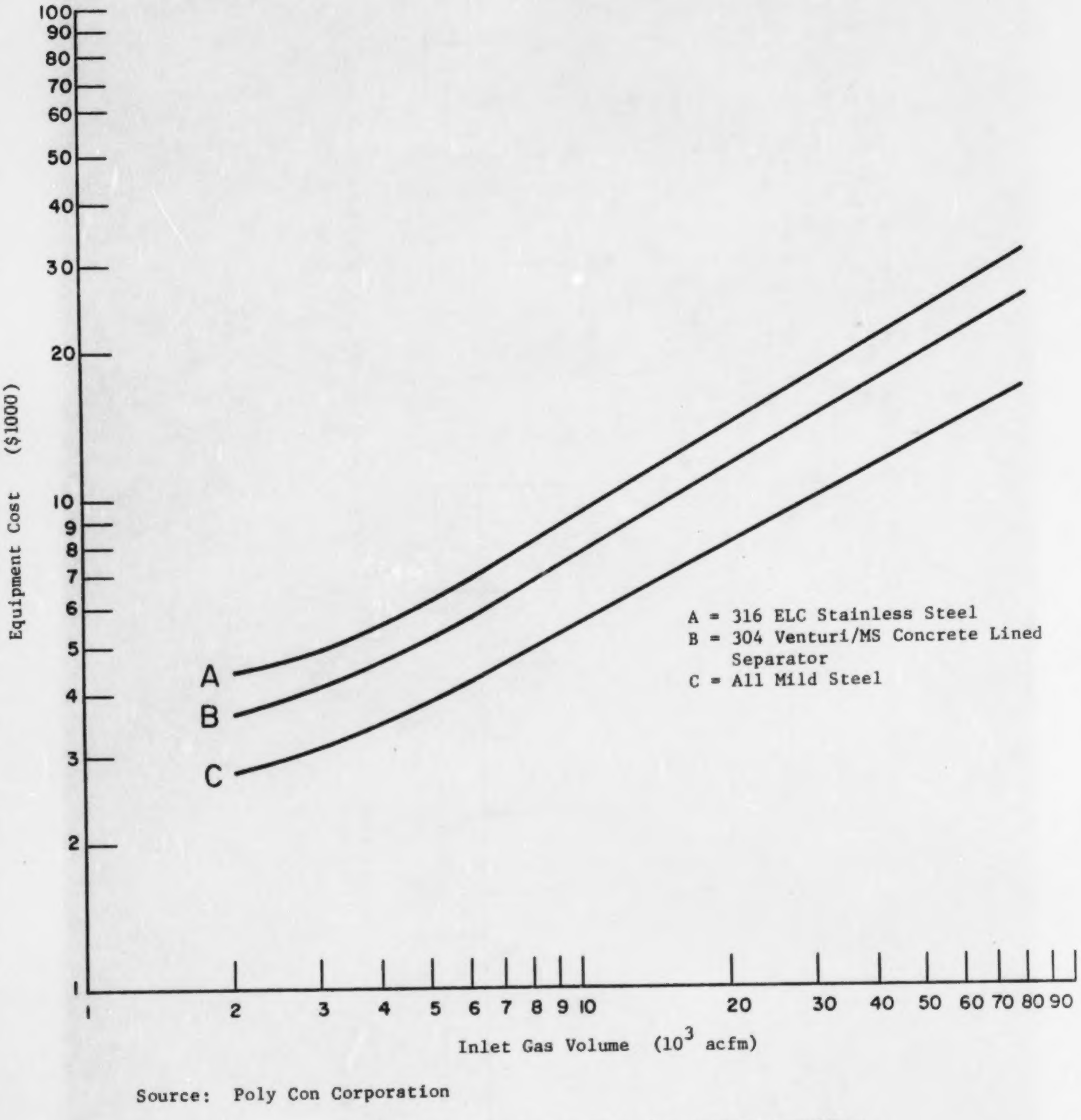
ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr)	ADDITIONAL PRODUCTION (thousand tons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	107	518	1	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1
FY72	138	667	1	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1
FY73	168	815	1	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1
FY74	199	963	2	--	--	--	0.1	0.1	0.1	0.1	0.1	0.2
FY75	230	1110	2	--	--	--	0.1	0.1	0.1	0.1	0.1	0.2
Totals -							0.5	0.5	0.5	0.5	0.5	0.7

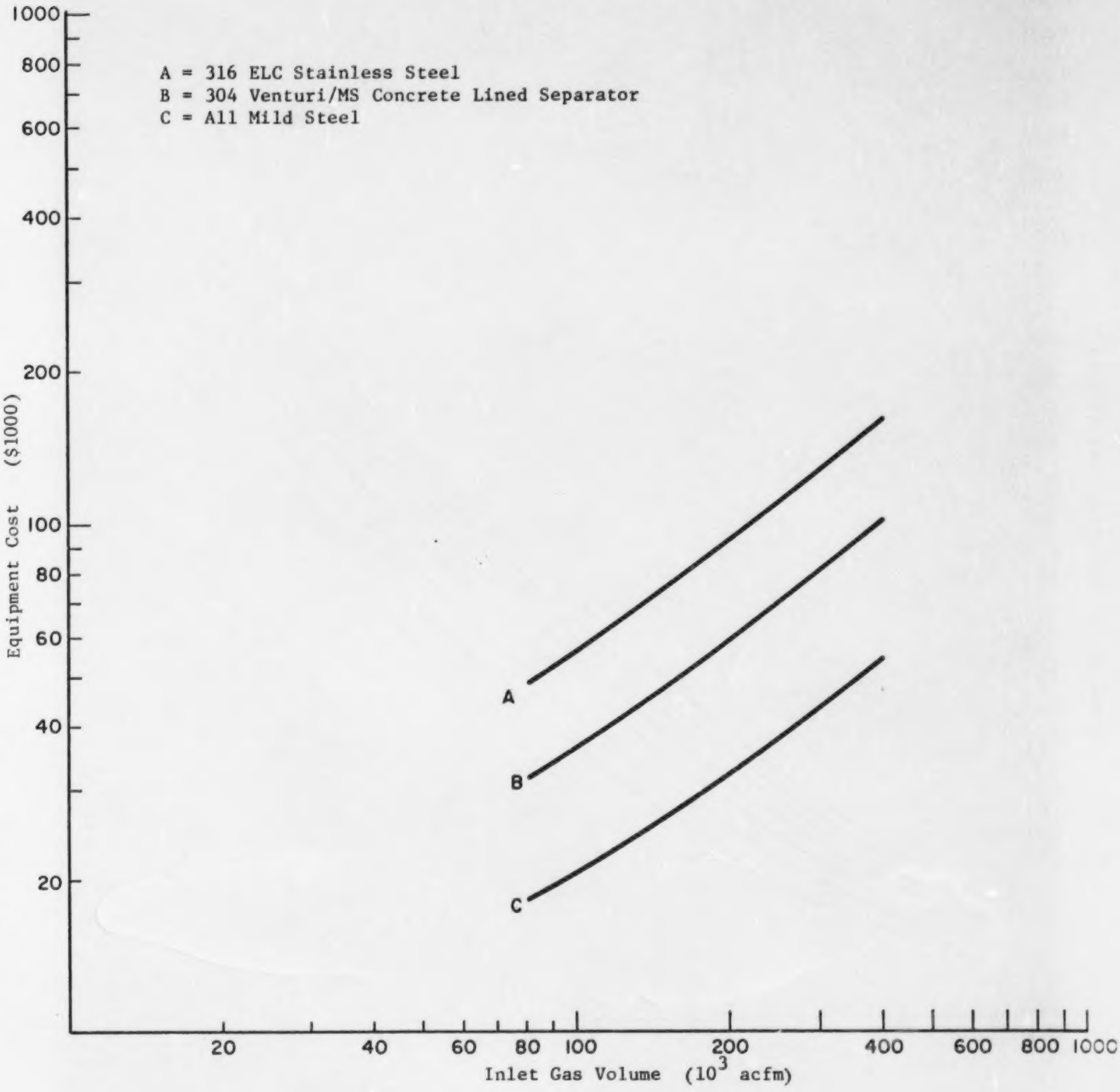
[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.



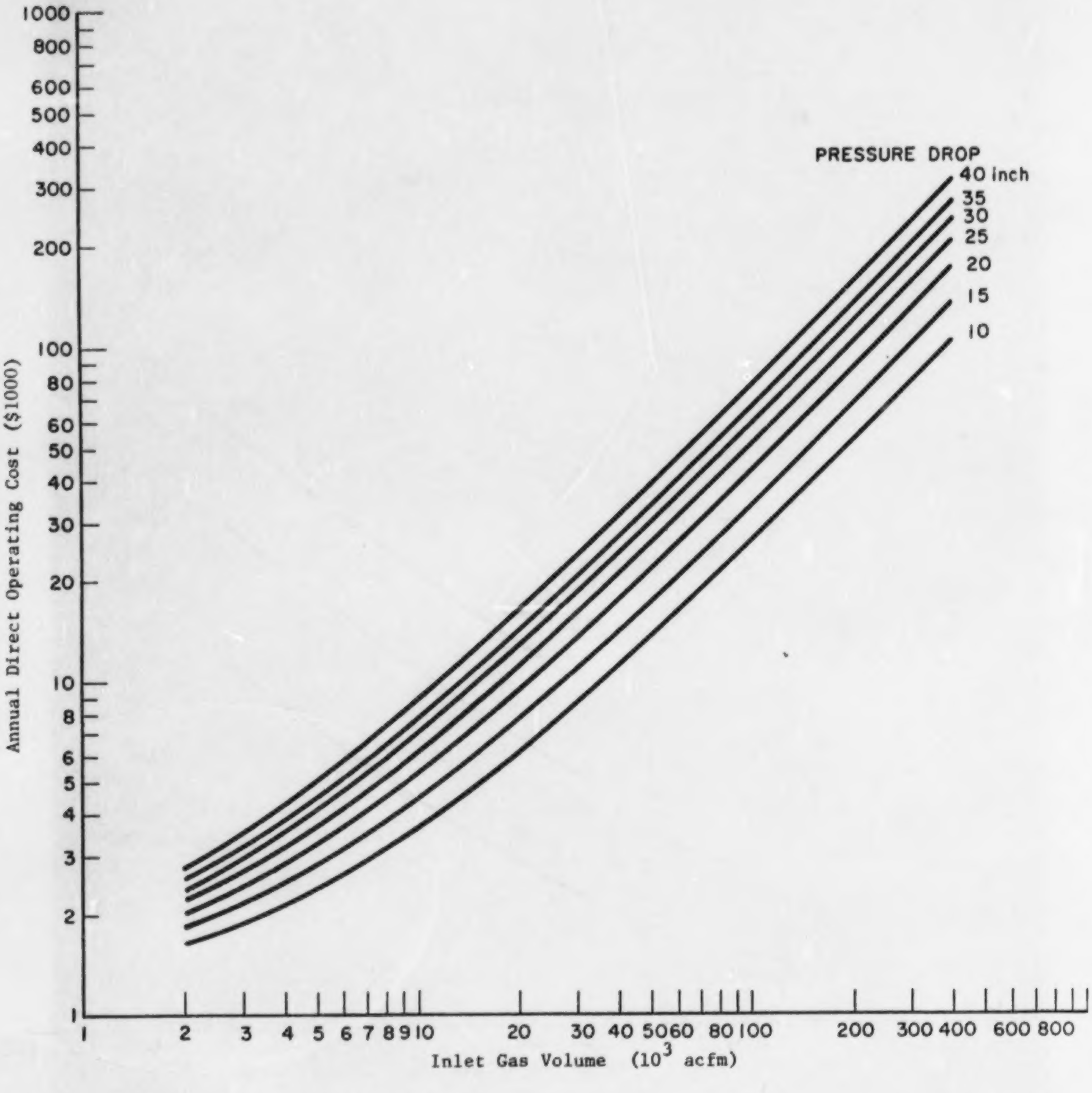
Source: Poly Con Corporation

Fig. 0-1. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. 0-2. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. 0-3. Annual Direct Operating Cost for Venturi Scrubbers.

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Appendix P

Petroleum Refining Industry

(SIC No. 2911)

Appendix P

Petroleum Refining Industry

I. INTRODUCTION

In 1967, the national annual capacity for the 262 petroleum refineries amounted to 4,210 million barrels; the annual production was 3,580 million barrels; and the value of shipments amounted to $20.3 billion. Capacity of the 134 refineries in the 100 metropolitan areas was 2,530 million barrels, and accounted for production of about 2,380 million barrels, or 66 percent of national production. Value of shipments was $13.5 billion, about 67 percent of the national total.

Although there is a variable number of sources of emissions in each petroleum refinery, a few sources account for the bulk of the pollutants. The major sources are catalyst regenerators which emit carbon monoxide, hydrocarbons, particulates, and sulfur oxides; combustion processes, which emit primarily sulfur dioxide; and storage facilities, which emit primarily hydrocarbons. The following 1967 emissions in thousands of tons represent the United States and 100 metropolitan areas, respectively: particulates, 96 and 48; sulfur oxides, 2100 and 923; hydrocarbons, [1] 932 and 587; and carbon monoxide, 2000 and 1080.

II. CONTROL OF EMISSIONS

The regulations and control methods which apply to petroleum refinery operations include all of the following: (a) the process weight rate regulation for particulate control, (b) maximum of 500 parts per million of sulfur oxides in exhaust gas, (c) the removal of 95 percent of carbon monoxide in exhaust gases, (d) the use of a floating roof to control hydrocarbon emissions from storage tanks, and (e) the removal of 90 percent or more of organic materials in exhaust gases for hydrocarbon reduction. The control methods which are normally applied to meet these standards are highly individualized, depending upon the specific process types. In general, however,

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[1] From storage evaporation, transfer operations, and catalytic cracking.

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particulates are controlled by the use of gas-cleaning equipment, sulfur oxides by sulfur recovery plants, hydrocarbons from storage tanks by floating roofs, and carbon monoxide by waste heat boilers. These control methods will increase average control efficiencies for particulates from 67 to 82 percent, for sulfur oxides from 37 to 50 percent, for hydrocarbons from 48 to 93 percent, and for carbon monoxide from 47 to nearly 100 percent (see Table P-2).

The Los Angeles Air Pollution Control District accepts the operation of sulfur recovery plants as sufficient to control sulfur oxides. Even though this technique does not reduce sulfur oxides in catalyst regenerator gas to 500 parts per million, it was used in this study since it is the only feasible control technique acceptable to the refining industry.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

A. Methodology

1. Crude Oil and Gasoline Storage

a) Cost Estimating Procedure

The total crude oil storage capacity for each region was based on a 30-day refinery supply, and gasoline storage capacity was based on 43 percent of this value[2/] [Refs. 1 and 2]. A model tank size of 80 thousand barrels was selected, and the total storage capacity in each region (based on refinery capacities) was divided by 80 thousand to determine the equivalent number of model tanks in the region. The fractional capacity remaining after accounting for all the model tanks was costed as a separate item and added to the model plant costs. Three-fourths of these tanks were assumed already to have floating roofs and submerged fill lines; therefore, no further control was required. Since the

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[2/] Later information indicated that nationwide crude oil storage capacity represented a 23-day supply and gasoline storage represented 17-day supply.

cost for converting to a floating roof tank and installing submerged filling techniques was considerably less than installing a new tank, it was assumed that all tanks would be converted and not replaced.

b) Engineering Process Data

Figure P-1 presents the data used to determine tank conversion costs. The tank size of 80 thousand barrels was chosen as the average based on talks with various knowledgeable people [Refs. 3 and 4] and personal observation of refinery tank farms. Operating and maintenance costs were not determined since these are low and are usually equal to or less than the value of the recovered gasoline and crude oil.

Emissions of hydrocarbons result from refinery activities including crude oil storage, gasoline storage, and gasoline transfer. The emission factors and percent control attainable with current technology is shown in Table P-1.

Table P-1

HYDROCARBON EMISSIONS AND CONTROL PERCENTAGES

Operation	Uncontrolled Emissions[a] of Hydrocarbons	Percent Control[a] Attainable
Crude oil storage	9 lb/1000 bbl	56
Gasoline storage	47 lb/1000 bbl	90
Gasoline transfer	11.5 lb/1000 gal turnover	40

[a] From data in Reference 5.

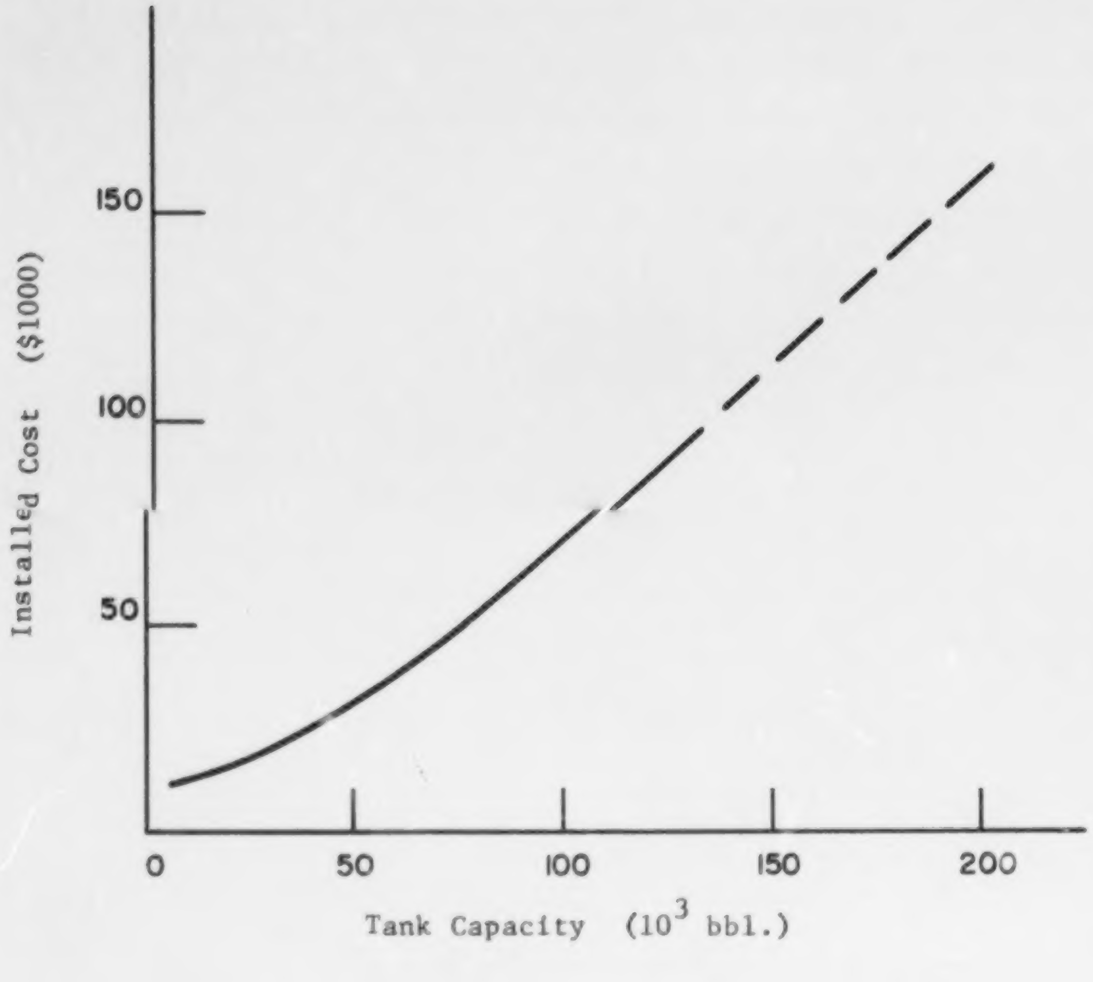

Fig. P-1. Installed Cost of Floating Roofs on Petroleum Storage Tanks.

In determining current emissions, the following assumptions were made for a typical metropolitan area:

1) Three-fourths of all crude oil storage tanks are controlled [Ref. 5].
2) Three-fourths of all gasoline storage tanks are controlled [Ref. 5].
3) One-half of all gasoline transfer operations are controlled [Ref. 5].
4) All gasoline capacity is turned over 10 times per year.
5) Gasoline storage equals 43 percent of crude oil storage.
6) A thirty-day supply of crude oil is stored.
7) All storage facilities in California are fully controlled.

2. Sulfur Recovery Plants

a) Cost Estimating Procedure

Sulfur oxide emissions were controlled by installing sulfur recovery plants at those refineries which did not already have them. The size of the sulfur recovery plants was based on each refinery's capacity and on estimated sulfur oxide emissions.

b) Engineering Process Data

Figure P-2 presents sulfur recovery plant costs based on information obtained from References 6, 7, and 8. Existing sulfur plant locations were also obtained from these references.

Since specific data on the composition of a refinery's crude oil or its exact processing techniques were not available, a general sulfur dioxide emission factor of 50 tons per 100 thousand barrels of crude oil throughput was used [Ref. 9]. Variations in this emission factor were made based on crude oil sulfur content. Thus, in the Gulf Coast and California areas, this factor was reduced by 30 percent; on the East Coast it was increased by 25 percent; and it was not changed for the balance of the country. Only 50 percent of this emission is amenable to recovery

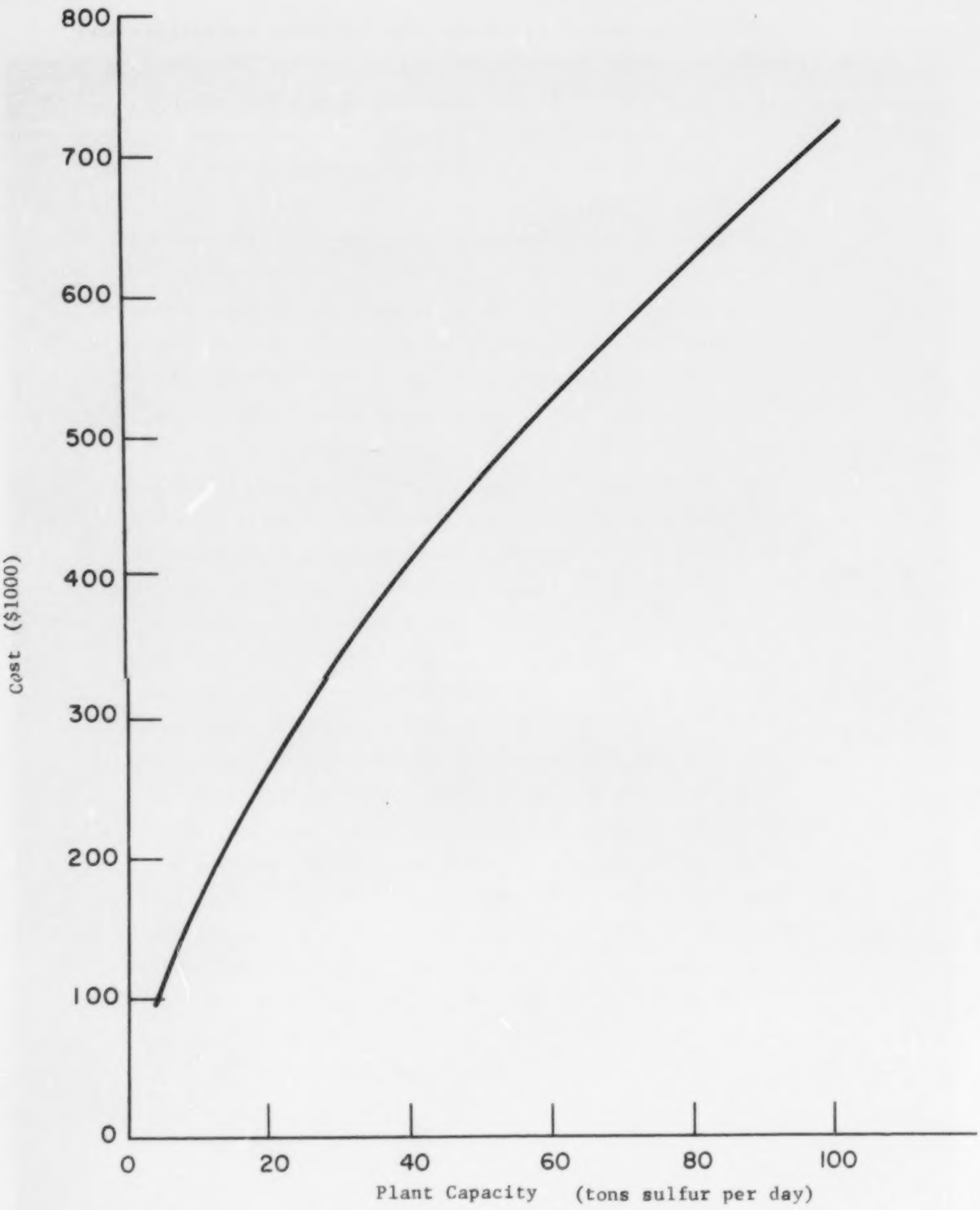

Fig. P-2. Sulfur Recovery Plant Costs.

in a sulfur plant [Ref. 10]. Since operation of sulfur plants smaller than 7 tons per day is not economically feasible, the smaller refineries (sulfur dioxide emissions less than 28 tons per day) were not included in the cost estimates.

3. Catalyst Regenerators

a) Cost Estimating Procedure

To meet the particulate regulation, only fluid catalytic cracking (FCC) units larger than 10 thousand barrels per day required additional controls. All smaller FCC units and all Thermofor (TCC) and Houdriflow (HCC) catalytic cracking units can meet the regulations with existing controls. In addition, all FCC units requiring control were costed separately, and the total metropolitan area cost was simply the sum of the FCC control costs within that area. Control costs were based on using a high-efficiency electrostatic precipitator; operating and maintenance costs were based on the size of the unit; and a 20 percent capital plus depreciation charge was used to derive the annual costs.

For controlling carbon monoxide and hydrocarbon emissions, the cost of a carbon monoxide (CO) boiler was estimated for each FCC unit. The eight HCC units located in the 100 areas already have CO boilers, and TCC units with their lower CO emissions are not generally amenable to control with a CO boiler and were not included in the cost estimate. Only 50 percent of the capital investment for these boilers was charged as an air pollution control cost since steam is generated in these units for inplant purposes [Ref. 11]. Annual charges were also not included as an air pollution cost since they are a general plant cost.

CO boiler costs were estimated according to the heat content of the exit gas stream and the available boiler cost data [Refs. 12 and 13]. Locations of existing CO boilers, when known, were taken into account. However, on a nationwide basis, approximately 25 boilers could not be located.

b) Engineering Process Data

Precipitator costs were based on the gas flow rate leaving the catalyst regenerator. Based on limited data [Refs. 12, 14, and 15], the following relationship between barrels of total feed and exit gas rate was determined:

$$\text{acfm} = \frac{2830 \text{ acfm}}{1000 \text{ bbl/day}} \times \text{feed rate (in 1000 bbl/day)} + 75{,}000 \text{ acfm}$$

With the exit gas rate known, cost functions relating cost and feed rate were prepared and used to determine total and annual charges [Ref. 16]. (See Figure P-3.)

Emissions of particulates from FCC units with normal process controls, but without electrostatic precipitators for air pollution abatement purposes, were based on 6.25 pounds of particulate per 1000 barrels[3/]; particulate emissions from Thermofor and Houdriflow units were based on 0.52 pounds per 1000 barrels.[4/] Estimates of controlled emissions were based on an electrostatic precipitator collection efficiency of 82 percent.

CO boiler costs are shown in Figure P-4. These costs could vary depending on the amount of supplementary fuel used to generate plant steam; however, the costs shown do represent that portion of the cost chargeable to air pollution control.

Uncontrolled emissions of CO from FCC units were based on 5.6 tons of CO per 1000 barrels total feed [Ref. 17]. Uncontrolled emissions from Thermofor units were based on 1.2 tons of CO per 1000 barrels total feed [Ref. 17]. There are no significant CO or hydrocarbon emissions from Houdriflow units since they are all presently controlled. In all cases units were assumed to operate 360 days per year. CO and hydrocarbon emissions from controlled units were assumed to be zero.

[3/] FCC units emit 0.10 pounds particulate per ton of catalyst [Refs. 14 and 17].

$$\frac{0.10 \text{ lb part.}}{\text{ton catalyst}} \times \frac{62.5 \text{ ton catalyst}}{1000 \text{ bbl total feed}} = 6.25 \text{ lb part. per 1000 bbl}$$

[4/] TCC and HCC units emit 0.04 pound particulate per ton of catalyst [Refs. 13 and 16].

$$\frac{0.04 \text{ lb part.}}{\text{ton catalyst}} \times \frac{13 \text{ ton catalyst}}{1000 \text{ bbl total feed}} = 0.52 \text{ lb part. per 1000 bbl total feed}$$

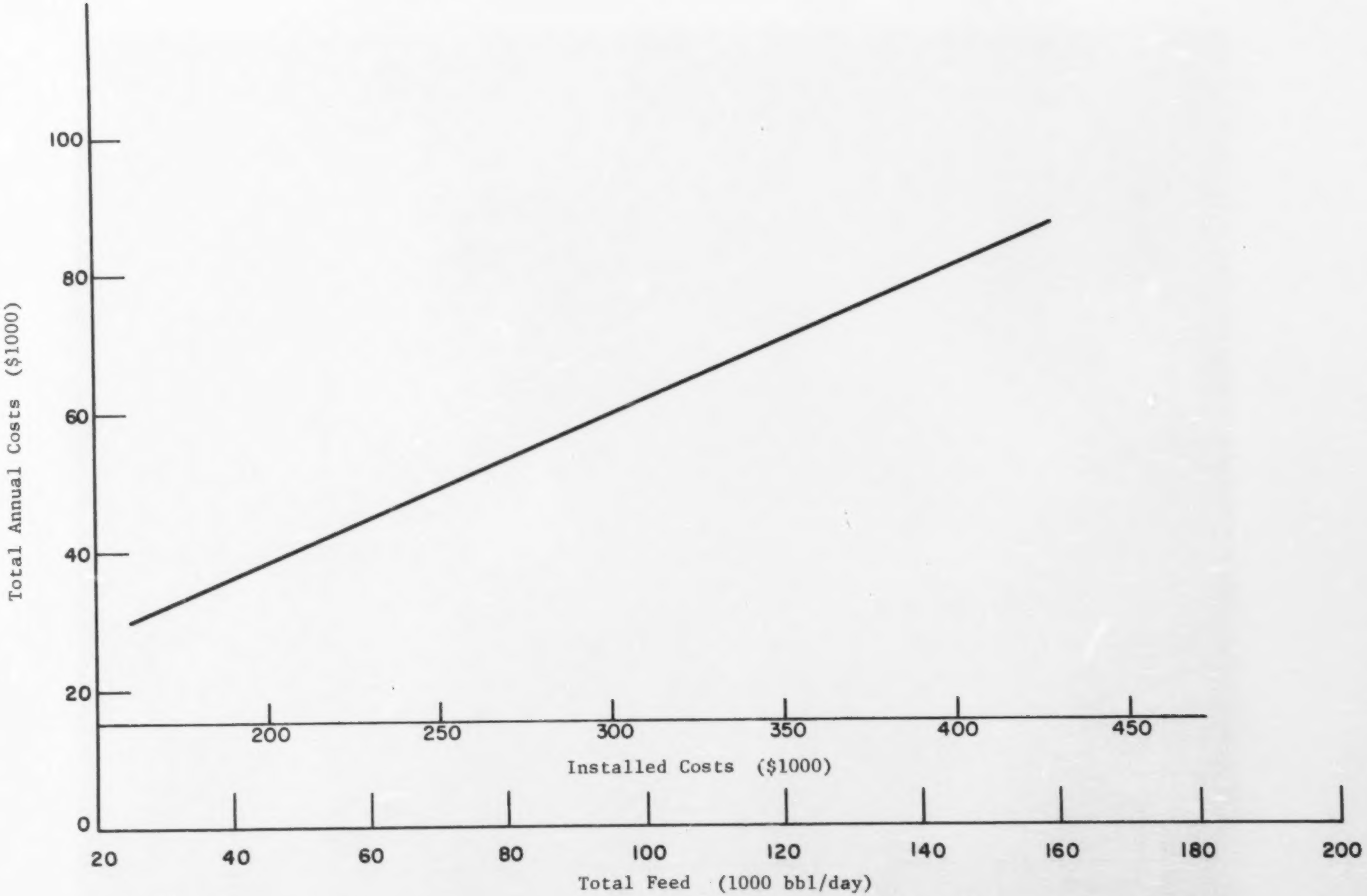

Fig. P-3. Annual and Installed Costs for Electrostatic Precipitators.

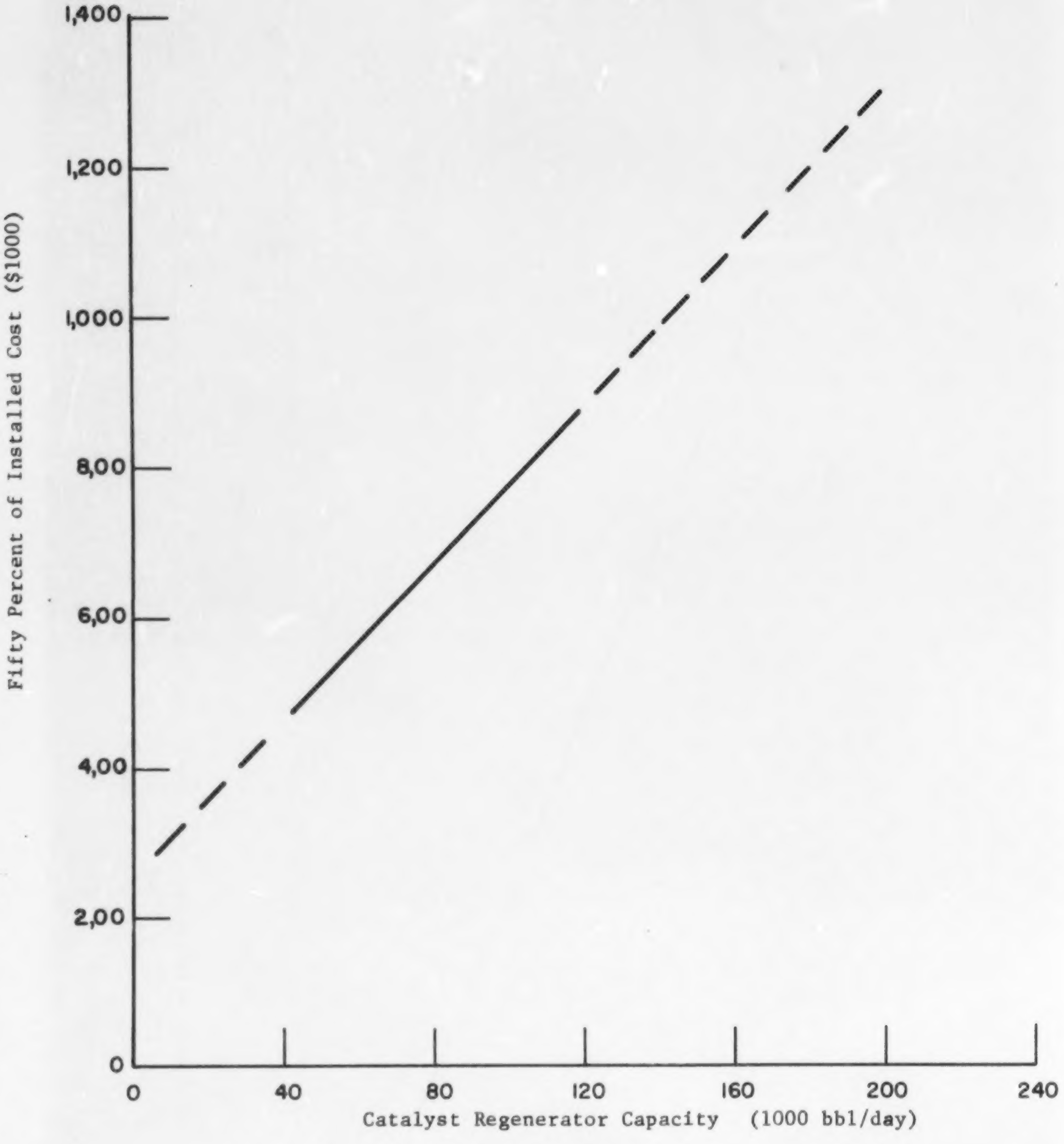

Fig. P-4. Cost of Carbon Monoxide Boilers.

Uncontrolled HC emissions from fluid units were based on 180 pounds HC per 1000 barrels total feed and those from Thermofor units were based on 57 pounds HC per 1000 barrels total feed [Ref. 17]. These figures can be converted to 32.4 and 10.3 tons HC per year per 1000 barrels total daily feed, respectively. In all cases, emissions from controlled units were assumed to be zero.

B. Estimated Costs

The resulting costs, which include credits for materials recovered or saved and take into account existing controls, were totalled for the 100 metropolitan areas; and are shown in Table P-2. Annual control costs average less than one cent per barrel capacity when the plan is fully implemented. Emissions would be reduced from 48 thousand tons of particulates to 26 thousand tons; 923 thousand tons of sulfur dioxide to 737 thousand tons; 587 thousand tons of hydrocarbons to 79 thousand tons; and 1080 thousand tons of carbon monoxide to 102 thousand tons by 1975. Total estimated investment costs amount to $80.3 million with estimated ultimate annual costs of over $3.6 million.

IV. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing production facilities (Section III) but also for additional capacity projected beyond the base year 1967. The projected growth costs were based upon the ultimate control levels of 82 percent for particulates, 50 percent for sulfur oxides, 93 percent for hydrocarbons, and 95 percent for carbon monoxide. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

Based on predictions of future production, the expected annual growth rate through FY 1975 was determined to be 3 percent [Ref. 18]. Capacity estimates, derived from the production estimates, were based upon achieving a capacity utilization rate of 90 percent by FY 1975.

Table P-2

PETROLEUM REFINING PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC[c]	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	48	923	587	1080	67.0	37.0	48.5	47.0						
FY71	46	910	587	1080	68.0	38.2	48.5	47.0	0.3	0.6	1.2	0.1	0.1	0.1
FY72	40	863	489	855	72.0	41.3	57.0	54.0	8.3	16.5	33.1	0.2	0.4	0.7
FY73	32	790	267	595	78.0	46.3	77.0	71.0	17.5	35.0	70.1	0.2	0.4	0.8
FY74	28	749	114	163	81.0	49.1	90.0	92.0	11.7	23.2	47.0	0.6	1.3	2.5
FY75	26	737	79	102	82.0	50.0	93.0	95.0	2.5	5.0	10.0	0.6	1.4	2.7
Total -									40.3	80.3	161.4	1.7	3.6	6.8

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO).

[c] Hydrocarbon emissions from storage evaporation, transfer operations, and catalytic cracking.

The results of the cost analysis of controlling the additional capacity are shown in Table P-3. As shown, costs in each year reflect immediate control of the incremental capacity at the ultimate control levels. Without the act in effect, for the 1967 base year capacity plus the additional capacity added after 1967, emissions in the 100 areas would amount to 63 thousand tons of particulates, 1,130 thousand tons of SO_2, 719 thousand tons of hydrocarbons, and 2,323 thousand tons of carbon monoxide by FY 1975. With the act in effect, emissions would be reduced to 34 thousand, 903 thousand, 97 thousand, and 124 thousand tons, respectively.

Table P-3

PETROLEUM REFINERIES

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (million barrels/yr)	ADDITIONAL PRODUCTION (million barrels/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC[c]	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	334	250	3	77	8	10	1.5	3.1	6.2	0.1	0.1	0.1
FY72	429	322	4	99	10	14	2.3	4.6	9.2	0.1	0.1	2.6
FY73	525	393	6	122	13	16	3.2	6.3	12.7	0.1	0.2	0.4
FY74	620	465	7	144	15	21	2.6	5.2	10.5	0.2	0.3	0.6
FY75	716	536	8	166	18	22	1.7	3.5	7.0	0.2	0.4	0.7
Totals -							11.3	22.7	45.6	0.7	1.1	4.4

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

[c] Hydrocarbon emissions from storage evaporation, transfer operations, and catalytic cracking.

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Appendix Q

Asphalt Batching Industry
(SIC No. 2951)

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Appendix Q

Asphalt Batching Industry

I. INTRODUCTION

Asphalt batching is the production of a road surface paving mixture from hot asphalt and stone aggregate that is crushed, dried, and heated prior to the batching process. Fine dust, the major emission, is released during this drying and heating of the stone aggregate.

During 1967, capacity of the estimated 1500 asphalt batching plants located in the United States was approximately 658.0 million tons; that of the 903 plants in the 100 metropolitan areas was 250.0 million tons. In 1967, the national production reached 216.0 million tons with 82.0 million attributed to the 100 areas. The value of shipments for the United States and the 100 areas was $1.5 billion and $0.6 billion, respectively.

II. CONTROL OF EMISSIONS

In 1967, particulate emissions, the major emission, totalled 522 thousand tons per year for the United States and 206 thousand tons per year for the 100 areas.

Currently, almost all plants have primary collection devices which yield a control level of about 80 percent. By 1975, an overall average control efficiency of 92.0 percent following primary collection will be required to satisfy the process weight rate regulation adopted for this study.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate control costs for the asphalt batching industry consisted of: (a) an evaluation of the various production processes found within the industry,

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(b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required emission levels, including process size - control system size relationships.

The processes considered in this study include the major source of dust in the industry, the aggregate drier, as well as secondary sources, which include aggregate elevators, vibrating screens, hot aggregate bins, weigh hoppers and aggregate mixers. The trend in the industry is to combine the off gases from the drier and all the secondary sources (captured in a so-called ventline) and send the resulting gas stream to a single collector [Ref. 1].

Uncontrolled emissions amount to 25 pounds of dust per ton of asphalt batched [Ref. 2]. Presently, it is estimated that the industry as a whole controls to a level of 80 percent; therefore, present emissions which are considered herein as uncontrolled amount to 5 pounds per ton of asphalt produced. Required removal efficiencies were calculated on the basis of the process weight rate standard and an uncontrolled emission rate of 5 pounds per ton. These are shown in Table Q-1.

Table Q-1

INCREMENTAL REMOVAL EFFICIENCIES REQUIRED

Process Size (tons/hour)	Incremental Efficiency Required (percent)
40	79
100	91
150	93
200	95

To achieve these removal efficiencies, it has been reported that multiple cyclones will be satisfactory to process sizes of 100 tons per hour, while for larger capacities venturi scrubbers with a pressure drop of 15 inches, w.g. will achieve required removals [Ref. 1]. In all cases, an 80 percent efficient primary collector was considered as process equipment.

To relate process size to control system size, a factor of 15 thousand s.c.f.m. (at an inlet temperature of 200° F) per 100 tons per hour was used [Ref. 3].

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Data regarding numbers, sizes, and locations of asphalt batching plants were sought for each individual state through a variety of sources; data for about half of the states were obtained. Some states listed plants by location and capacity; others reported location and total annual capacity or annual production; some listed only the total asphalt paving mix used annually in state-financed construction (primarily roads and streets); and many had or provided no data. For all cases, except the first, production and capacities were estimated according to the metropolitan area population (weighted when possible by data on plant location). All capacities were scaled to an hourly production rate because asphalt batching plants have widely varying operating schedules.

Drying-heating capacities for aggregate were calculated assuming 95 percent of final product weight was aggregate. No information about aggregate drying-heating kiln capacity was obtained; however it was reported that for the great majority of plants, there is only one kiln [Ref. 4]. Distributions of estimated kiln capacities and control system sizes were constructed. Unpublished cost data for control equipment provided by the PolyCon Corporation and presented in Figures Q-1 through Q-5 at the end of this appendix provided control cost estimates for a range of plant sizes (see Table Q-2). These average costs were then multiplied by estimated capacities for each area to determine each area's emission control costs.

Table Q-2

ASPHALT BATCHING EMISSION CONTROL COSTS

Number of Plants with Known Capacity	Kiln Gas Volume (10^3 acfm)	Equivalent Plant Capacity (tons of mix per hr.)	Costs ($1000)	
			Investment	Annual
3	4.5	30	2.95	1.19
40	9.0	60	4.05	1.61
65	13.5	90	5.55	2.11
208	18.0	120	13.0	9.8
123	22.5	150	17.0	12.1
150	27.0	180	18.6	13.9
106	31.5	210	20.2	16.3
35	36.0	240	31.6	17.5
10	40.5	270	23.2	19.2
13	45.0	300	24.4	20.9
2	49.5	330	25.6	22.4
9	54.5	360+	27.0	24.4

[a] Costs for emission controls from 0.5 to 1.5 tons per batch are for a multicyclone; remaining costs are for 15" w.g. wet scrubber.

B. Estimated Control Costs

The resulting costs were totalled for the 100 metropolitan areas and are shown in Table Q-3. Annual control costs would average approximately $0.74 per ton of annual capacity when the plan is fully implemented.

The emission of particulates would be reduced from 206 thousand tons in 1967 to approximately 82 thousand tons by 1975. The investment cost for this level of control would total $24.5 million, with ultimate annual cost of $18.5 million.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing production (Section IV.B.) but also for anticipated increases in production in the asphalt batching industry beyond the base year of 1967. The projected growth costs were based on the expected ultimate particulate control level of 92 percent following primary collection. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An average annual production growth rate of 6.5 percent was used in this study [Ref. 5]. The capacity estimates derived from the production estimates were based upon achieving 90 percent utilization of capacity by 1975.

The results of the cost analysis of controlling the incremental production through 1975 are shown in Table Q-4. As shown, costs in each year reflect immediate control of the incremental production at the ultimate control efficiency. By 1975, without the act in effect, emissions would reach 306 thousand tons of particulates from the 1967 capacity plus the additional capacity added after 1967. With the act in effect, emissions would be reduced to 122 thousand tons.

Table Q-3

ASPHALT BATCHING PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	206	--	--	--	80.0	--	--	--						
FY71	200	--	--	--	80.6	--	--	--	0.6	1.2	1.8	0.4	0.9	1.4
FY72	171	--	--	--	83.4	--	--	--	2.7	5.3	8.0	2.4	4.9	7.4
FY73	126	--	--	--	87.7	--	--	--	4.3	8.5	12.8	5.7	11.4	17.1
FY74	94	--	--	--	90.8	--	--	--	3.2	6.5	9.7	8.1	16.2	24.4
FY75	82	--	--	--	92.0	--	--	--	1.5	3.0	4.5	9.2	18.5	27.8
Total -									12.3	24.5	36.8	25.8	51.9	78.1

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table Q-4

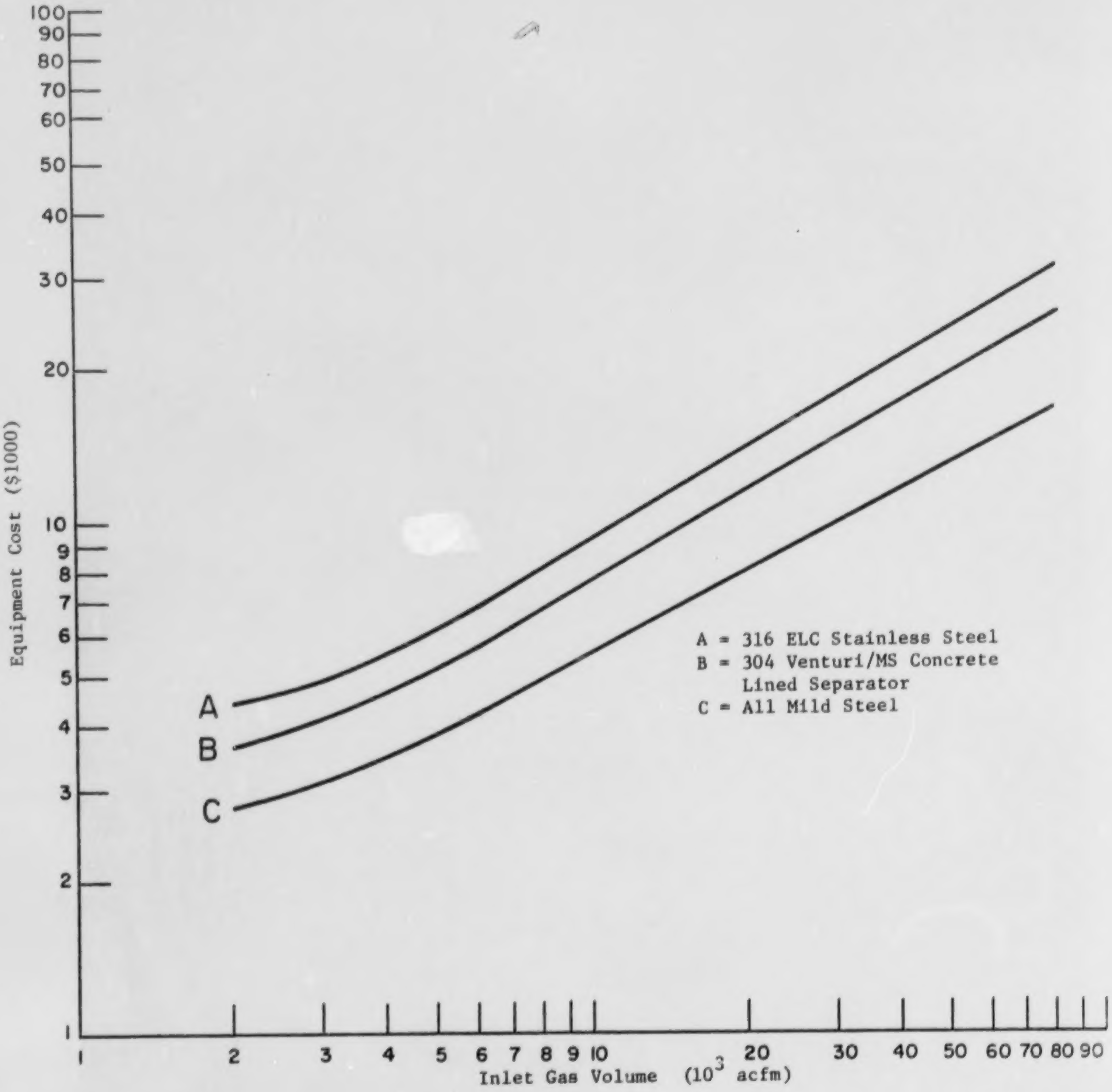
ASPHALT BATCHING PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/hour)	ADDITIONAL PRODUCTION (million tons/year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	57	19	18	--	--	--	0.8	1.7	2.5	0.6	1.3	2.0
FY72	73	24	24	--	--	--	1.0	2.0	3.0	1.6	3.2	4.8
FY73	89	29	29	--	--	--	1.1	2.3	3.4	2.7	5.4	8.2
FY74	105	35	34	--	--	--	1.0	2.1	3.2	3.7	7.4	11.2
FY75	122	40	40	--	--	--	0.9	1.8	2.7	4.5	9.0	13.5
Totals -							4.8	9.9	14.8	13.1	26.3	39.7

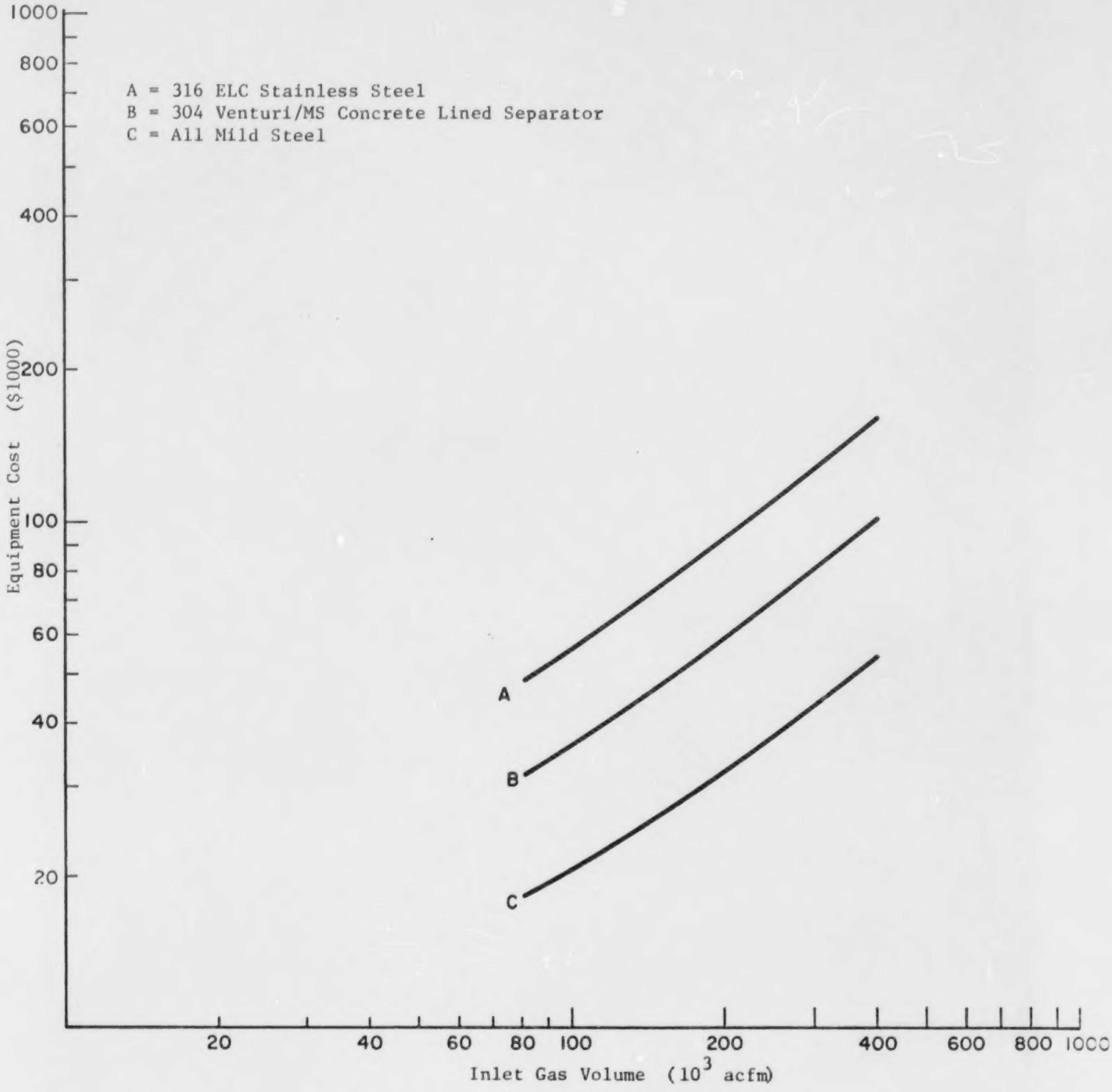
[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.



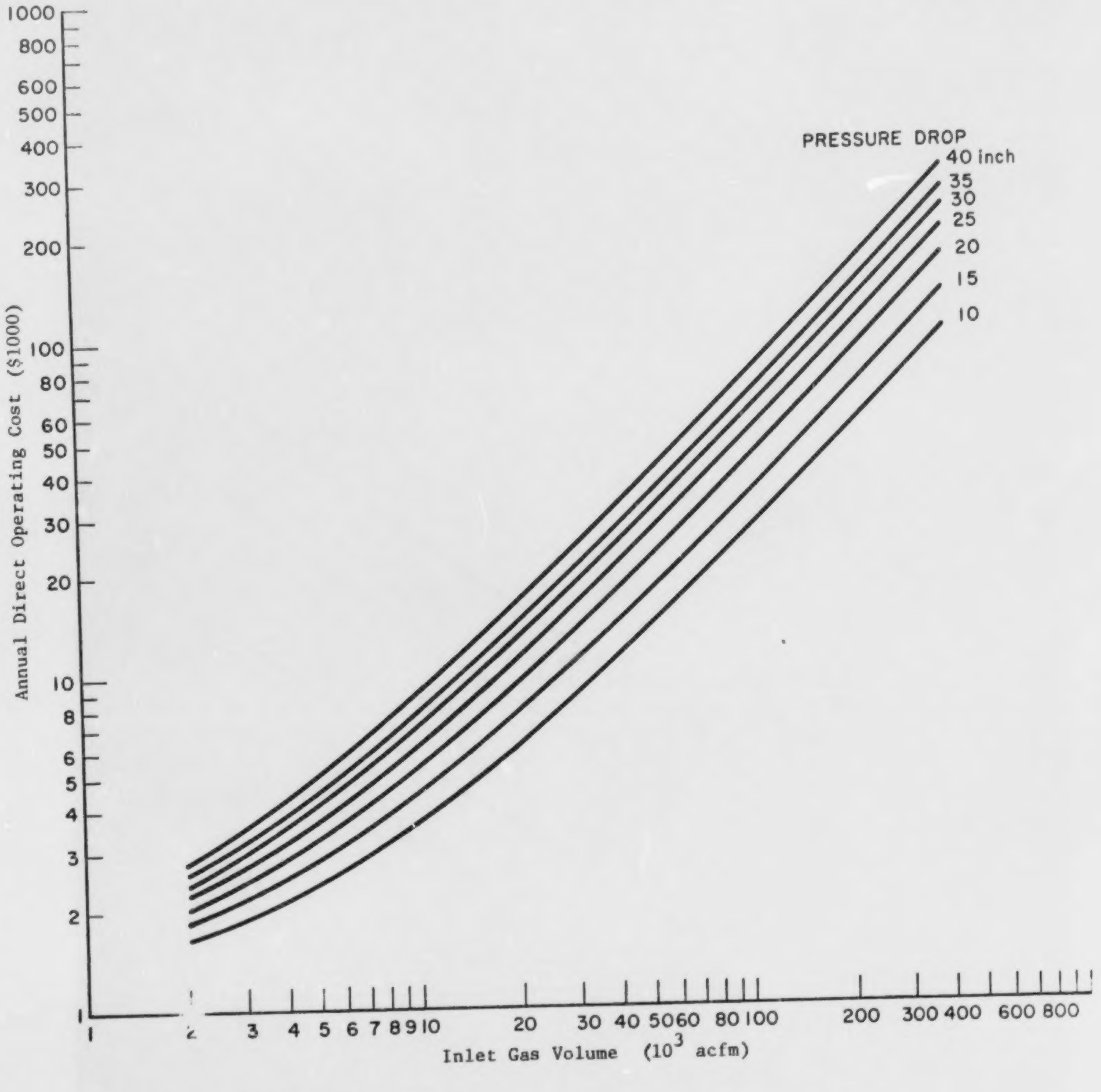
Source: Poly Con Corporation.

Fig. Q-1. Equipment Cost for Venturi Scrubbers.



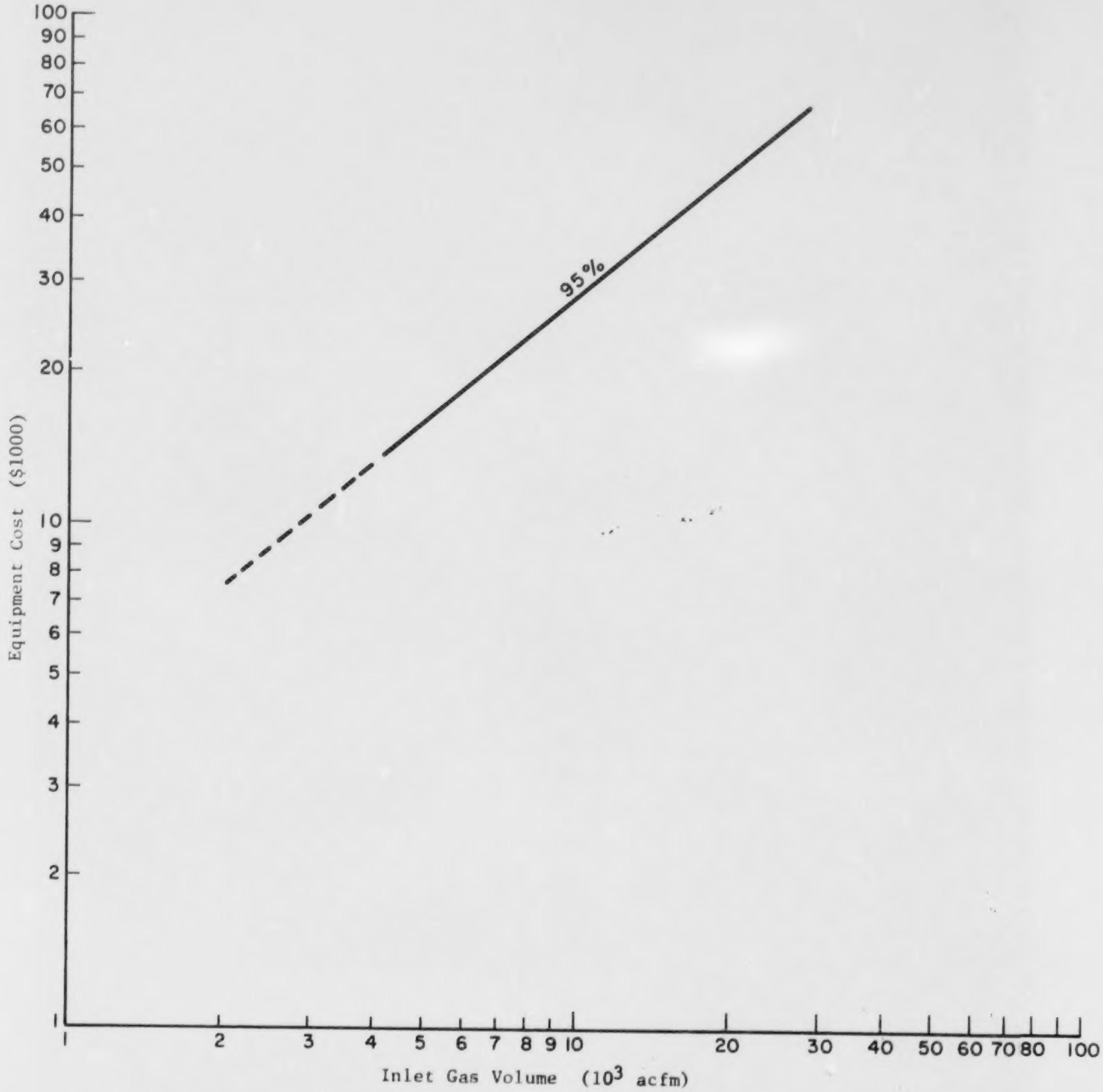
Source: Poly Con Corporation.

Fig. Q-2. Equipment Cost for Venturi Scrubbers.



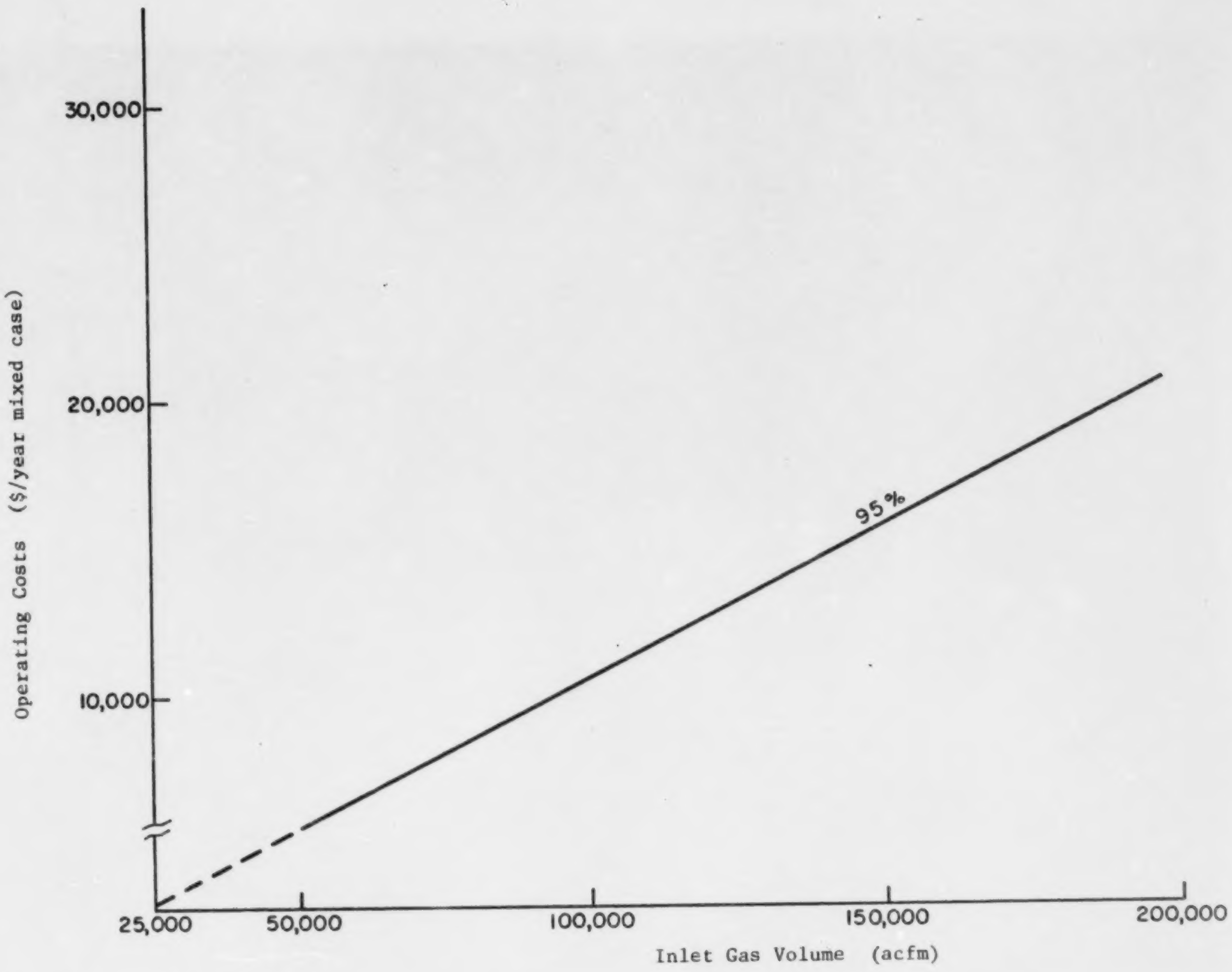
Source: Poly Con Corporation.

Fig. Q-3. Annual Direct Operating Cost for Venturi Scrubber.



Source: Poly Con Corporation.

Fig. Q-4. Equipment Cost for Multi-tube Collectors.



Source: Poly Con Corporation.

Fig. Q-5. Annual Operating Cost for Multi-tube Collectors.

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Appendix R

Cement Industry
(SIC No. 3241)

Appendix R

Cement Industry

I. INTRODUCTION

Portland cement accounts for 98 percent of all cement made in the Nation; therefore, this report deals only with this type.

In 1967, capacity for the 176 cement plants located in the United States was 578.0 million barrels; production was 378.0 million barrels; and value of shipments amounted to approximately $1.2 billion. For the 92 plants in the 100 areas, capacity was 279.0 million barrels; production was 192.0 barrels; and value of shipments was $0.6 billion.

In manufacturing cement, a combination of ingredients is crushed, ground, mixed, and then fired in kilns to about 2700° F, producing an intermediate product which is ground again to a fine powder. There are two manufacturing processes used by the industry: the wet and the dry processes. Of the two different processes, the wet process produces 58 percent of the cement and emits 38 pounds of dust per barrel to the dry processes's 46 pounds. Particulate emissions for the United States and the 100 metropolitan areas in 1967 were 908 million tons and 525 million tons, respectively.

II. CONTROL OF EMISSIONS

Although there are some particulate emissions from all the manufacturing steps, the major source is the kilns. For the same production, dry process kilns emit about 21 percent more dust than wet process kilns. Almost all kilns have at least a primary dust collector, resulting in an overall collection efficiency of 86 percent. By installing secondary collectors on the kilns, the industry will be able to meet the process weight standard for particulate control and obtain about 99 percent overall control.

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III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate control costs for the cement industry consisted of: (a) an evaluation of the various production processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required levels, including process size - equipment size relationships.

The primary difference with respect to pollution between the wet and dry processes is the state in which the ground raw material is fed into the kiln. The major unit processes involved are: crushing and grinding, drying (dry process only), clinker production (calcining), and final grinding. Dusts from crushing and grinding operations present only minor air pollution problems as these are essentially closed systems, and the dust collected is returned to the unit from which it was collected. The same is most often true of the drier off-gases which are usually vented to either grinding or calcining control systems. This study focuses on controlling particulate emissions from the calcining operation. The kiln represents the major source of particulate emissions in the cement industry, which is not well controlled at present.

Totally uncontrolled emissions from wet process kilns average 38 pounds per barrel[1/] of cement produced, while the average from dry process kilns is 46 pounds per barrel produced [Ref. 1]. The calcining operation is controlled to some degree. Table R-1 reflects an estimate of the present status of control for the industry.

[1/] A barrel equals 376 pounds of cement.

Table R-1

PRESENT CONTROL STATUS FOR THE CEMENT INDUSTRY

Control Systems	Plants Controlling (percent)	Control Efficiency (percent)
No control	5	0
Cyclone	5	70
Multicyclone	10	85
Electrostatic precipitator (old)	15	90-95[a]
Electrostatic precipitator (new)	10	96-97
Electrostatic precipitator[b] or fabric filter	55	> 99

[a] Ninety-five percent can be achieved if precipitator is in series with multicyclone.

[b] New electrostatic precipitator in series with multicyclone.

Source: Reference 2 and informed industry observers.

On the basis of the process weight rate standard, ultimate particulate removal efficiencies were calculated for both wet and dry process kilns. These are shown in Table R-2.

Table R-2

ULTIMATE PARTICULATE REMOVAL EFFICIENCIES REQUIRED

Kiln Capacity (1000 barrels/day)	Percent Efficiency Required	
	Wet Process	Dry Process
1	97.6	97.8
2	98.2	98.4
4	99.3	99.5
6	99.4	99.6
8	99.6	99.8
10	*	99.9

*Not applicable.

To achieve these removal efficiencies, it was established that the most effective control system for wet process kilns is a combination of a precleaner plus an electrostatic precipitator, while the system of choice for dry process kilns is a precleaner plus a fabric filter [Ref. 3]. The precleaner in each case must be considered process equipment because the captured particulates are always placed back in the kiln. On the other hand, the fine particulates collected by the precipitator or the fabric filter is often too high in alkali concentration and therefore cannot be returned to the process without further processing.

The relationships between production rate and equipment size were calculated for both wet and dry process kilns. The relationships are shown in Table R-3.

Table R-3
PRODUCTION RATE VERSUS GAS VOLUME

Production Rate (1000 barrels/day)	Gas Volume (10^3 acfm)	
	Wet Process	Dry Process
0.5	20	24
1.0	40	48
3.0	120	144
5.0	200	240
7.0	280	336
9.0	360	432
10.0	*	480

*Not applicable.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Each plant in the nation was identified by location, total capacity, and process type (wet or day) in a current list from Rock Products [Ref 4]. Another list from this source identified all plants installed since 1960 by total capacity, process type, number and capacity of kilns, and kiln emission control equipment [Ref. 5]. When a plant in the second list had two or more kilns, they had the same capacity. This was then assumed as the standard design for all plants for the purposes of estimating costs.

All plants in the second list (six of which were within the 100 metropolitan areas) are controlled sufficiently to meet the process weight rate standard, and thus were excluded from the costing procedure. Due to the lack of control information on a plant-by-plant basis, all other plants were assumed to have only a primary cyclone.

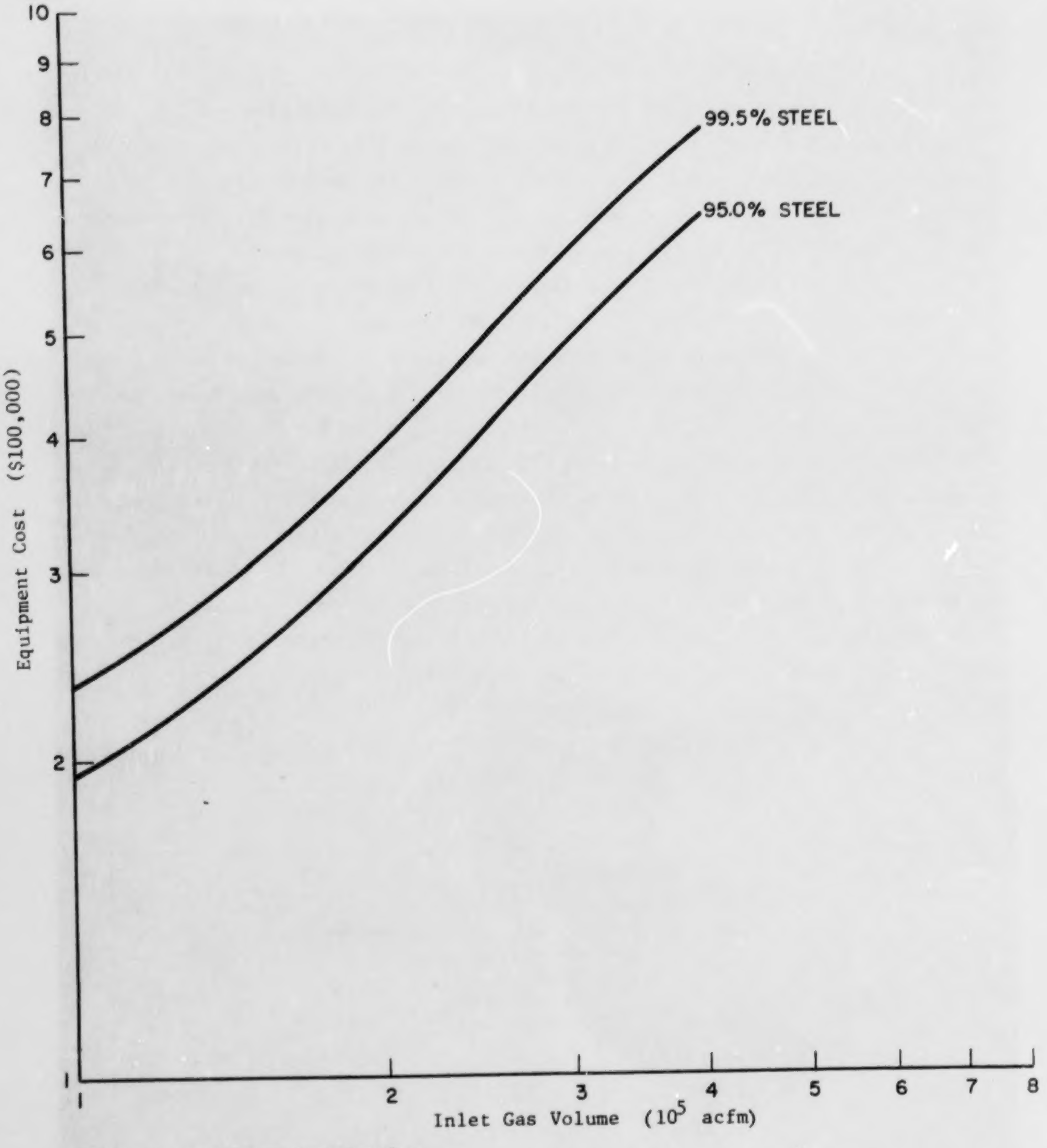
Wet process kilns were assigned high efficiency electrostatic precipitators and dry process kilns were assigned baghouses for secondary control. The cost of each type of control was calculated separately on the basis of gas volume. Control equipment cost data (Figures R-1 to R-3) were obtained from the analyses by Edmisten and Bunyard [Ref. 6] and from information supplied by the Poly Con Corporation [Ref. 7]. Emission control costs for the wet and dry processes are presented in Table R-4.

Table R-4

CEMENT PLANT EMISSION CONTROL COSTS

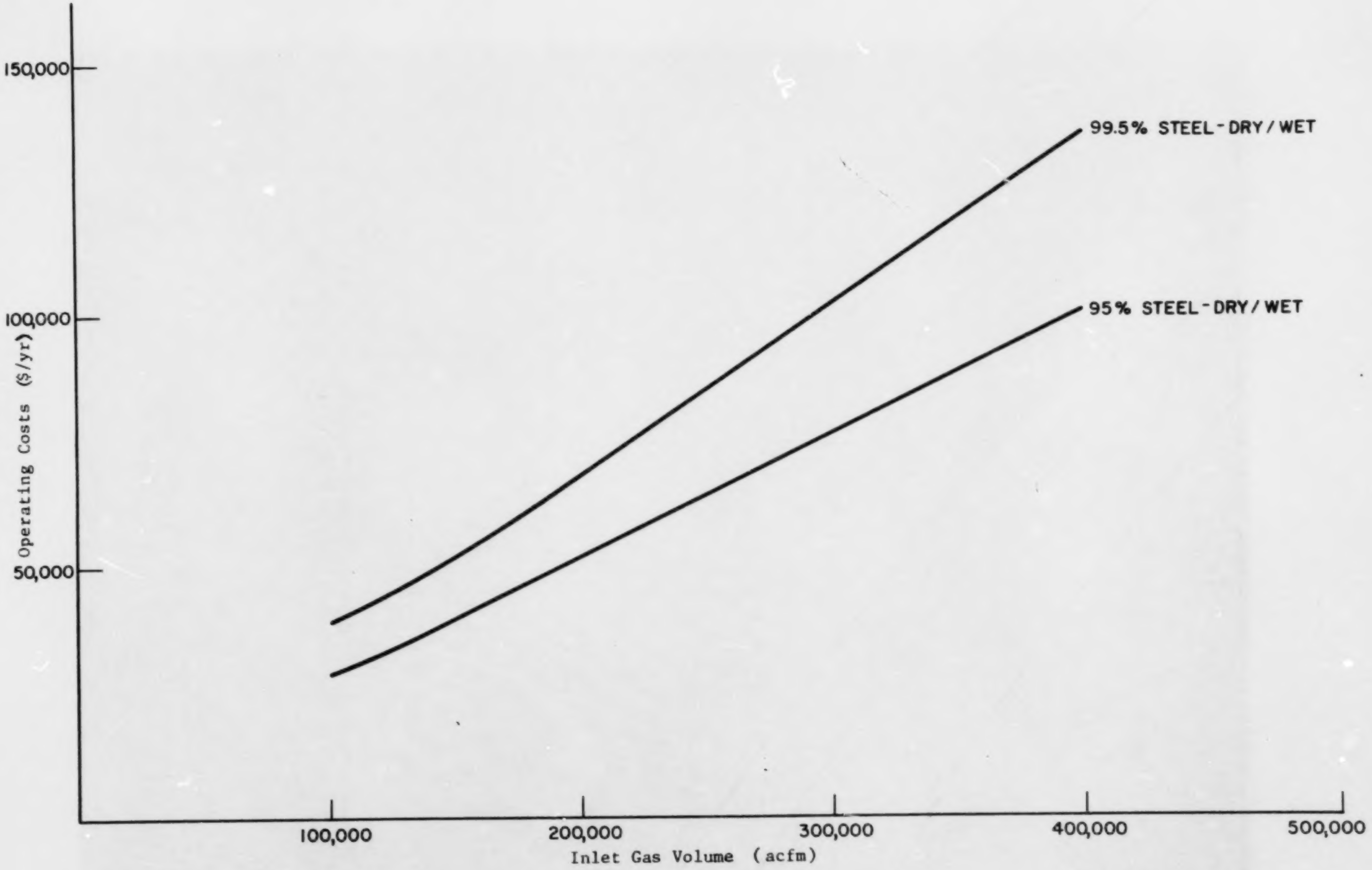
Plant Capacity (1000 barrels/day)	Emission Control Costs[a] ($1000)			
	Wet Process (high efficiency ESP)		Dry Process (fabric filter)	
	Investment	Annual	Investment	Annual
1	7.15	1.72	6.33	2.34
2	14.50	3.34	18.25	6.75
4	48.90	11.72	79.90	31.10
6	73.50	17.70	135.00	50.00
8	111.00	26.60	232.00	85.90
10	--	--	354.50	131.40

[a] The tabulated control cost values were graphed versus capacity because of the complex relationships of variable emission control levels and the cost credit calculated for presently-existing 90-percent control. Costs for all plants were then read from the graphs as a function of plant capacity.



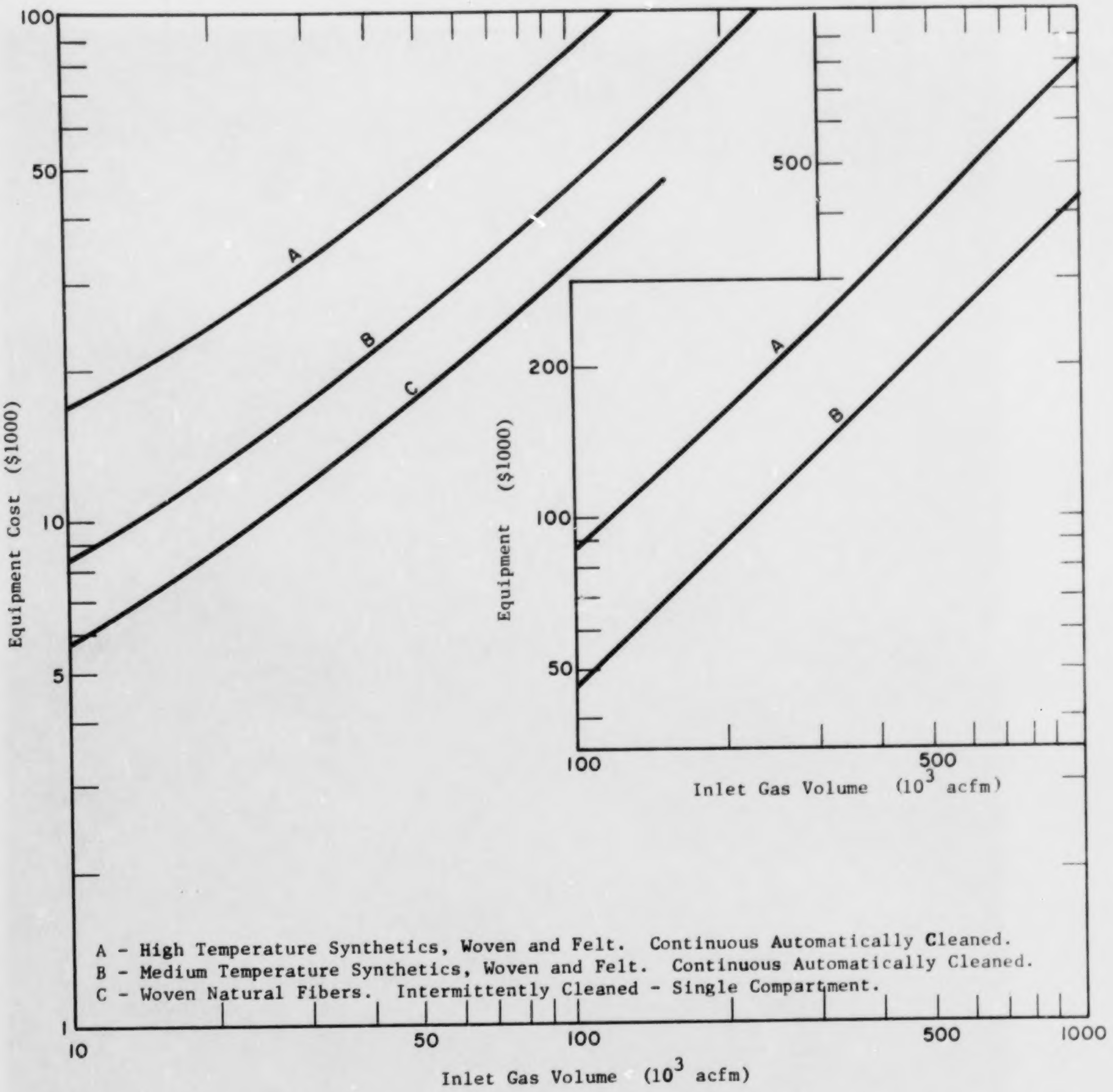
Source: Poly Con Corporation.

Fig. R-1. Equipment Cost for Electrostatic Precipitator.



Source: Poly Con Corporation.

Fig. R-2. Operating Costs for Electrostatic Precipitator.



Source: Edmisten, N. G. and F. L. Bunyard, "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources." Presented at the annual meeting of the Air Pollution Control Association, New York, June 1969.

Fig. R-3. Equipment Cost of Fabric Filters.

The control cost for each kiln in the detailed Rock Products list was calculated and used to find the weighted average cost per barrel of capacity, and graphs of costs for the two process types were plotted as functions of capacity. Cost per plant was read directly from the graph and totalled for the 100 metropolitan areas.

B. Estimated Control Costs

The resulting cost estimates are shown in Table R-5. Annual control costs would average approximately $0.02 per barrel of cement producing capacity when the plan is fully implemented.

The emission of particulates would be reduced from over 525 thousand tons in 1967 to approximately 37 thousand tons by 1975. The investment cost for this level of control would total $18.3 million, with an annual cost of $5.6 million by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were also calculated for increased production in the cement industry after the base year of 1967. The projected growth costs were based on the expected ultimate particulate control level of 99.0 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth. An average annual growth rate of 5.0 percent was used to estimate production increase between 1967 and FY 1975 [Ref. 8]. The capacity estimates, derived from the production estimates, were based on achieving 90 percent utilization of capacity by FY 1975. The costs of controlling the additional capacity are shown in Table R-6. As shown, costs in each year reflect immediate control of the incremental capacity at the ultimate control efficiency. For the 1967 capacity plus the additional capacity added after 1967, without the act, particulate emissions in the 100 areas would reach 723 thousand tons by 1975. With the act in effect, emissions would be reduced to 51 thousand tons.

Table R-5

CEMENT PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	525	--	--	--	86.0	--	--	--						
FY71	510	--	--	--	86.4	--	--	--	0.5	0.7	0.9	0.1	0.2	0.3
FY72	420	--	--	--	88.8	--	--	--	2.7	3.6	4.5	0.9	1.2	1.6
FY73	246	--	--	--	93.5	--	--	--	4.8	6.4	8.0	2.4	3.3	4.1
FY74	99	--	--	--	97.4	--	--	--	4.0	5.4	6.7	3.8	5.0	6.3
FY75	37	--	--	--	99.0	--	--	--	1.6	2.2	2.7	4.2	5.6	7.1
Total -									13.6	18.3	22.8	11.4	15.3	19.4

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table R-6

CEMENT PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand barrels/yr)	ADDITIONAL PRODUCTION (thousand barrels/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	6,690	33,600	6	--	--	--	0.1	0.1	0.2	0.1	0.1	0.1
FY72	8,600	43,200	8	--	--	--	0.1	0.2	0.2	0.1	0.1	0.1
FY73	10,500	52,800	10	--	--	--	0.2	0.2	0.3	0.1	0.2	0.2
FY74	12,400	62,400	12	--	--	--	0.2	0.2	0.3	0.2	0.2	0.3
FY75	14,300	72,000	14	--	--	--	0.1	0.1	0.2	0.2	0.3	0.4
Totals -							0.7	0.8	1.2	0.7	0.9	1.1

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix S

Lime Industry
(SIC No. 3274)

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Appendix S

Lime Industry

I. INTRODUCTION

Lime is produced in the form of quicklime, hydrated lime, and burned dolomite from quarried lime-bearing stone. Lime products are used mainly in construction, the manufacture of cement, or as a flux in the manufacture of products such as steel. The principal manufacturing step is the high temperature kiln operation that converts limestone to lime. The major pollutants emitted by operations in the industry are particulates in the form of lime dust, carbonates of calcium and magnesium, calcium sulfate, and fly ash. Kilns cause the most severe air pollution problem. Rotary kilns, which account for about 80 percent of production, emit approximately 10 times the amount of particulates emitted by vertical kilns per unit of production. A minor amount is emitted from limestone quarrying, transportation, preparation, lime handling, hydrating, and other operations, but these were not considered in this study for reasons given in Section III of this appendix.

In 1967, the national production amounted to 18.0 million tons. The Nation's 135 plants have an annual capacity of about 25.4 million tons and the 67 plants within the 100 metropolitan areas accounted for about 9.6 million tons, or 38 percent of total capacity. Production was about 7.7 million tons in the 100 areas. Value of shipments for the Nation and 100 areas was $0.2 billion and $0.1 billion, respectively. Nationally, in 1967, the industry emitted about 450 thousand tons of particulates while in the 100 regions emissions amounted to 251 thousand tons. Rotary kilns emit approximately 10 percent of the product as particulates whereas vertical kilns emitted only 1 percent.

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II. CONTROL OF EMISSIONS

Vertical kilns, in general, are uncontrolled and their dust emissions need to be reduced by 50 to 90 percent, depending on kiln capacity, to comply with the process weight rate standard for particulates. Although rotary kilns are generally controlled to a level of about 80 percent, they need additional controls to meet the above-mentioned regulation. Gas-cleaning equipment was assumed to provide the additional emission control needed for both kiln types. About 92 percent of present emissions would be eliminated resulting in a 96-percent level of overall collection efficiency.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering data and information required to estimate control costs for the lime industry consisted of: (a) an evaluation of the various production processes found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an engineering evaluation to select the most satisfactory control systems to achieve the required levels, including equipment cost - process size relationships.

At the lime plant, the kiln operation is the major source of uncontrolled particulate emissions. Rotary kilns have been found to emit between 5 to 15 percent by weight of the lime produced. Vertical kilns emit significantly less dust, amounting to only about 1 percent of the lime produced. In addition to the emissions from kiln operations, which represent a major portion of dust generated, there are emissions from other operations. Limestone quarrying and transportation cause localized emissions for which efficient solutions are not available. Other than moderately effective dust suppression techniques at the quarry site and improvement of the road from the quarry to the lime plant, little else can be done at present. Limestone crushing and screening operations represent a potentially significant source of particulate emissions. Generally, however, plants which have well constructed buildings with adequate dust ventilation systems enclosing the crushing and screening operations may be considered satisfactorily controlled. This is the case with most modern plants. In older plants which have poorly constructed buildings and inadequate ventilation systems, the dust remains a problem only in the building and the immediate surrounding area. Lime hydrating, processing, and packaging are significant sources of noxious material; however, the use of adequate dust ventilation and control systems is quite widespread in this area of the plant.

Various types of lime kilns are presently used by the industry. Of these, rotary and vertical kilns produce the major percentage of lime and emit the major quantity of particulates. If uncontrolled, rotary kilns emit approximately 200 pounds of particulates per ton of lime produced while vertical kilns emit about 20 pounds of particulates per ton of lime [Ref. 1]. At present, rotary kilns are generally controlled with dry mechanical collectors resulting in average reductions of about 80 percent. Vertical kilns in general are presently uncontrolled. Control efficiencies were calculated to comply with the process weight rate standard. These are shown in Table S-1.

Table S-1

ULTIMATE CONTROL EFFICIENCY REQUIRED

Capacity (tons/day)	Control Efficiency Required (percent)	
	Rotary Kiln	Vertical Kiln
10	*	52.4
50	*	78.6
100	97.8	79.8
200	98.1	83.8
300	98.8	*
400	98.9	*
500	99.2	*
600	99.3	*

*Not applicable.

Control systems to achieve required control limits were selected on the basis of incremental control required as well as on industry experience. For rotary kilns, medium energy (15" w.g.) venturi scrubbers were assumed as the secondary collector. For vertical kilns, cyclonic wet scrubbers (6" w.g.) were chosen as the basis for the control cost estimates. To relate process size to control equipment capacity, the estimated gas volumes shown in Table S-2 were used.

Table S-2

LIME KILN GAS VOLUMES

Kiln type	Unit Volume (acfm/ton/hour)
Rotary	5500
Vertical	3200

Adapted from data in Reference 2.

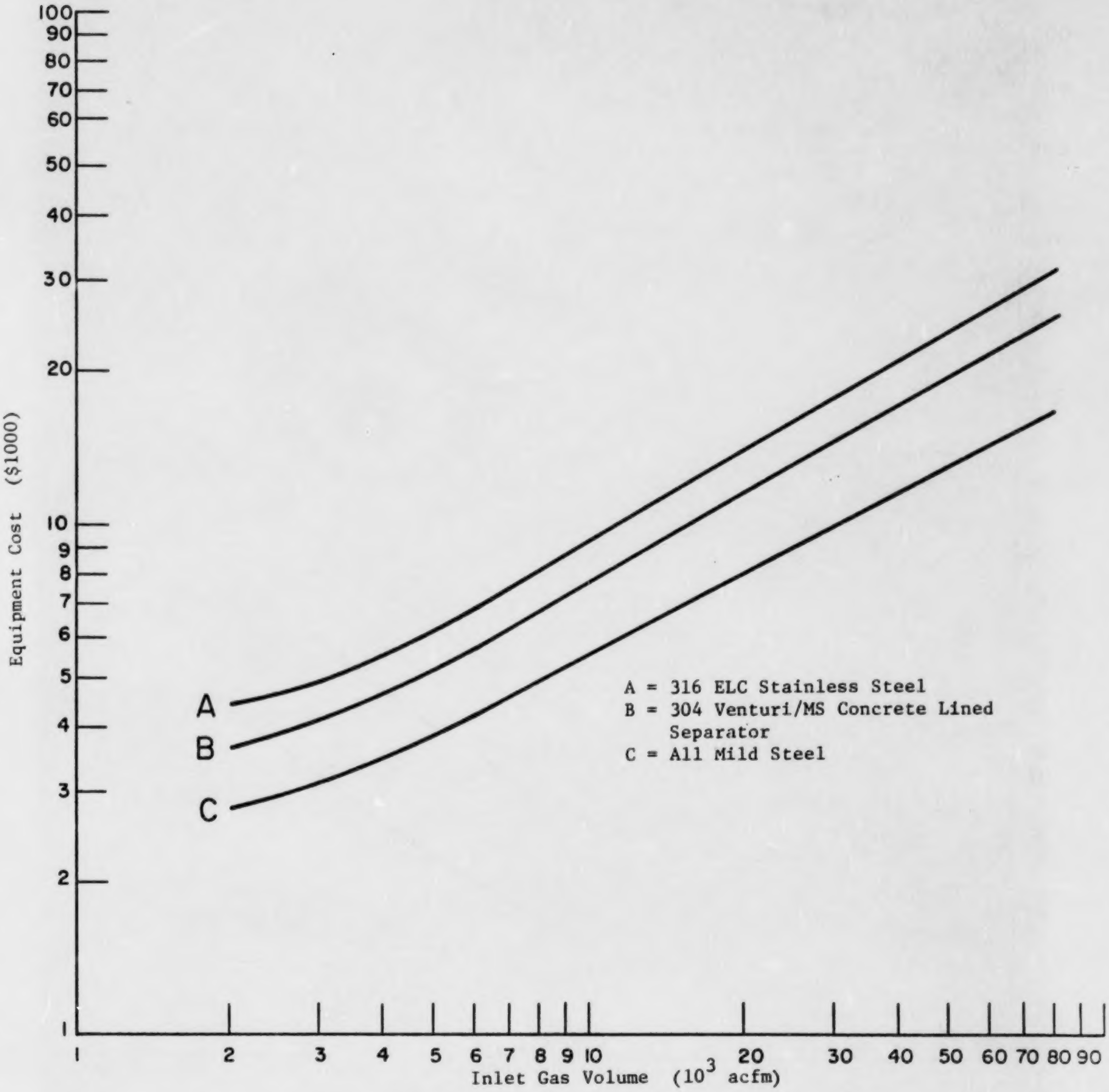
Equipment cost - process size relationships [Ref. 3] for the control equipment selected are presented in Figures S-1 through S-5. For both types of equipment, stainless steel was selected as the construction material with an installed cost to equipment cost ratio of two.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

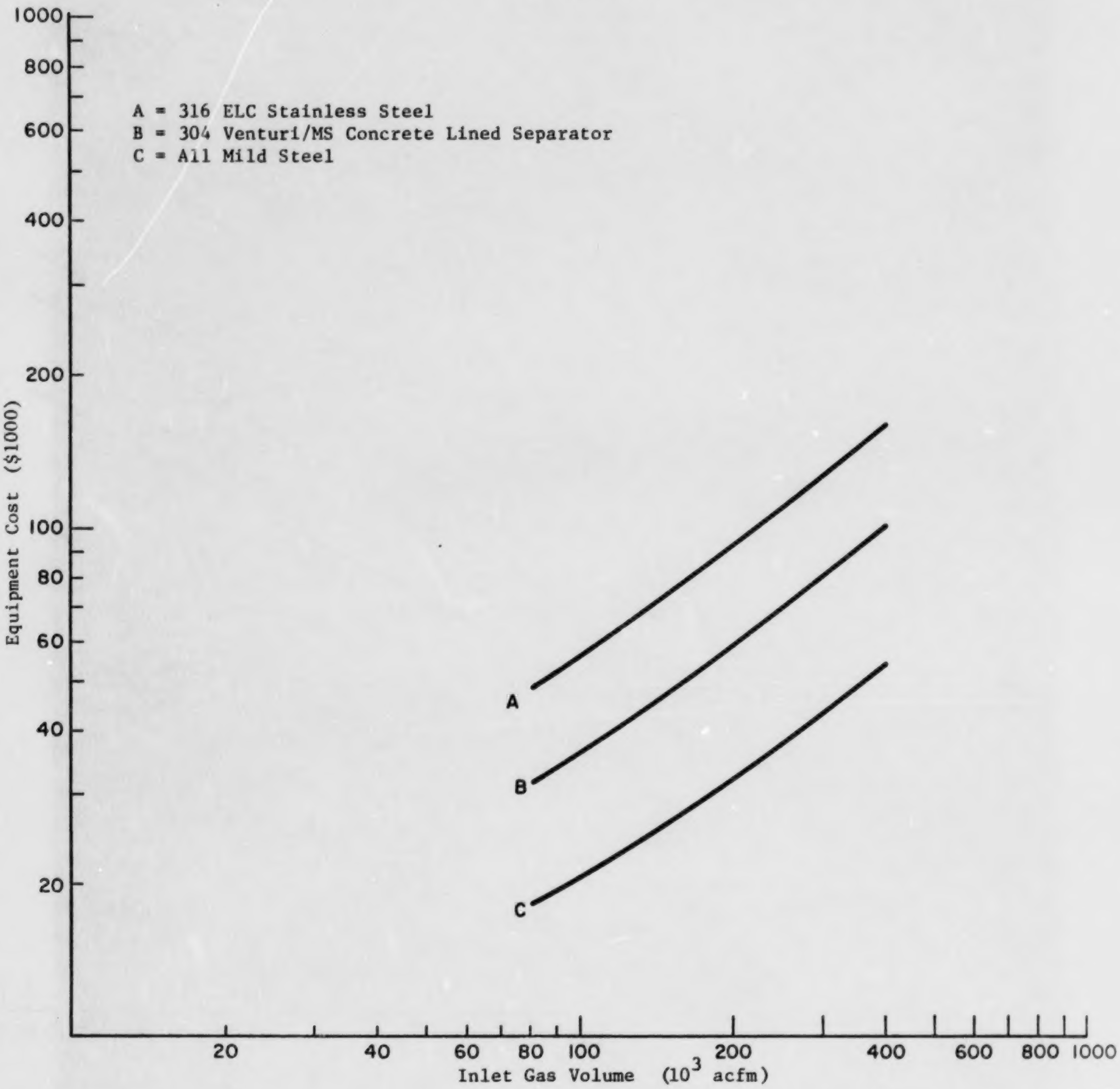
The data available to describe the lime industry were limited. One list of plants by location was used to form a list by metropolitan area [Ref. 4]. Another list furnished by the U.S. Bureau of Mines gave the number and capacity of plants by states, but the number and capacity, or both, were lacking for a few states [Ref. 5]. Capacities of the recently installed rotary kilns were obtained from several kiln manufacturers.

Because of the limited data, the costing method was indirect. The average plant capacity was calculated for each state; if data on a state were insufficient, the average capacity was assumed to be the national value. The total capacity was then calculated for each area.



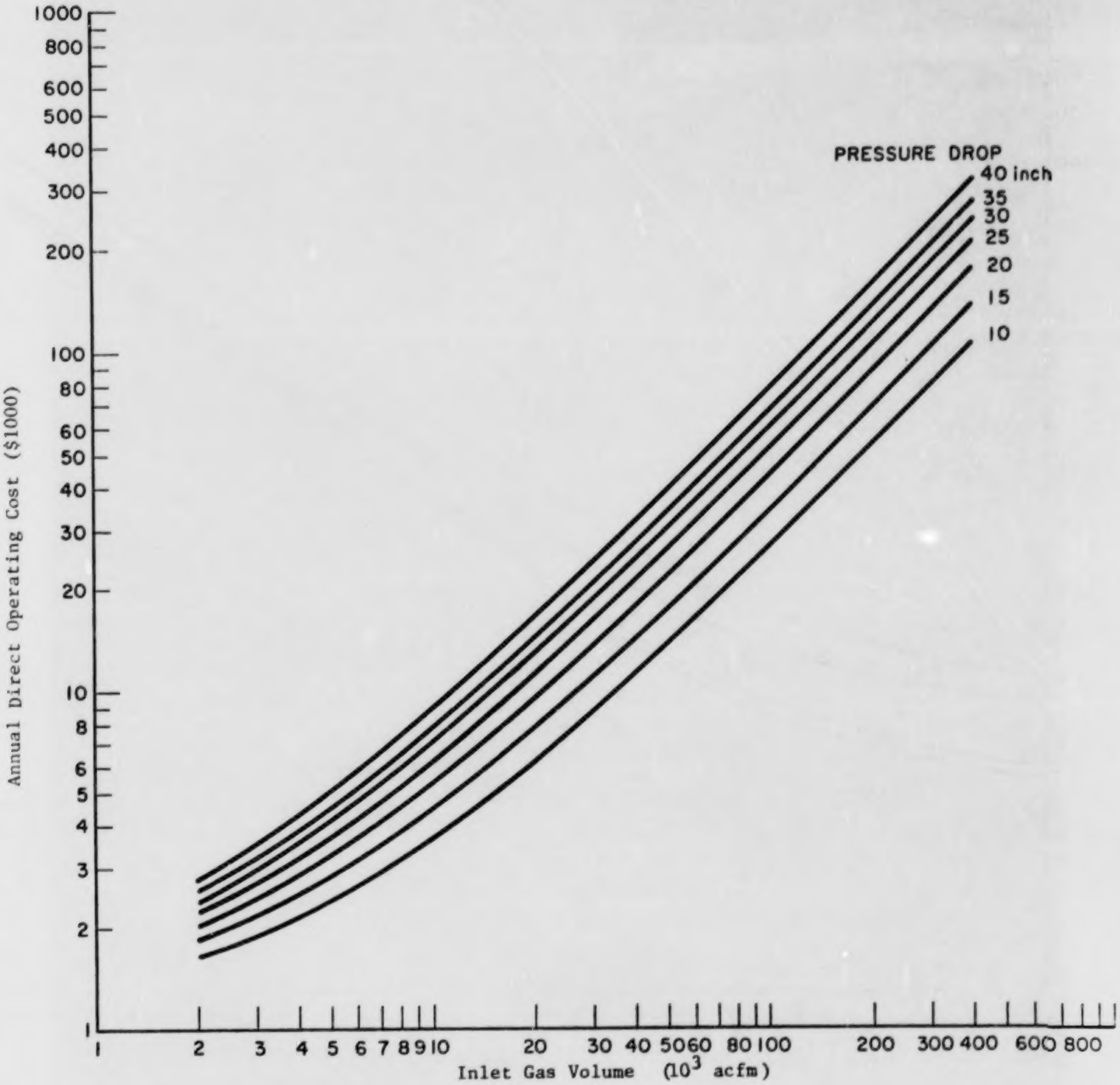
Source: Poly Con Corporation.

Fig. S-1. Equipment Cost for Venturi Scrubbers.



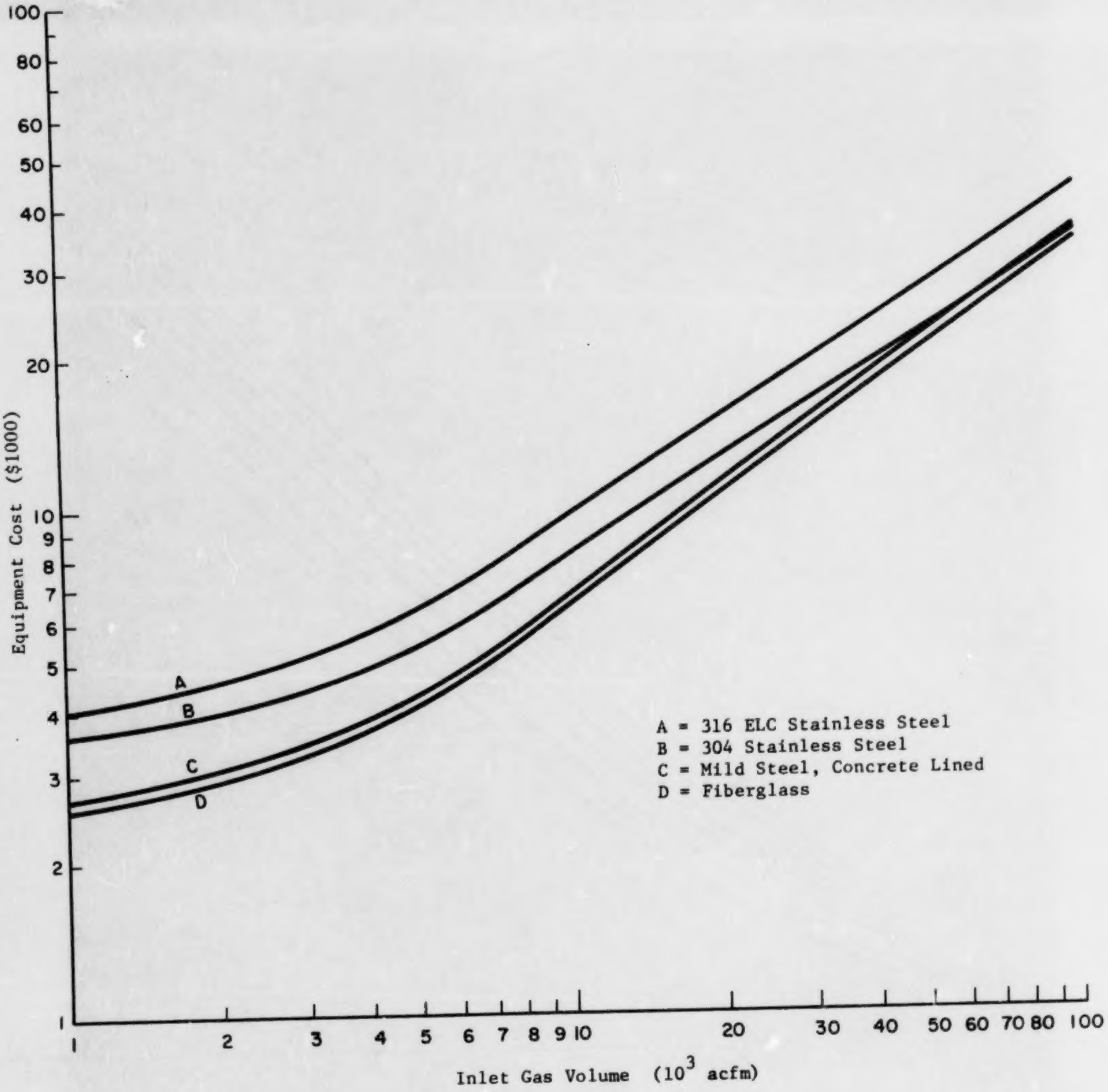
Source: Poly Con Corporation.

Fig. S-2. Equipment Cost for Venturi Scrubber.



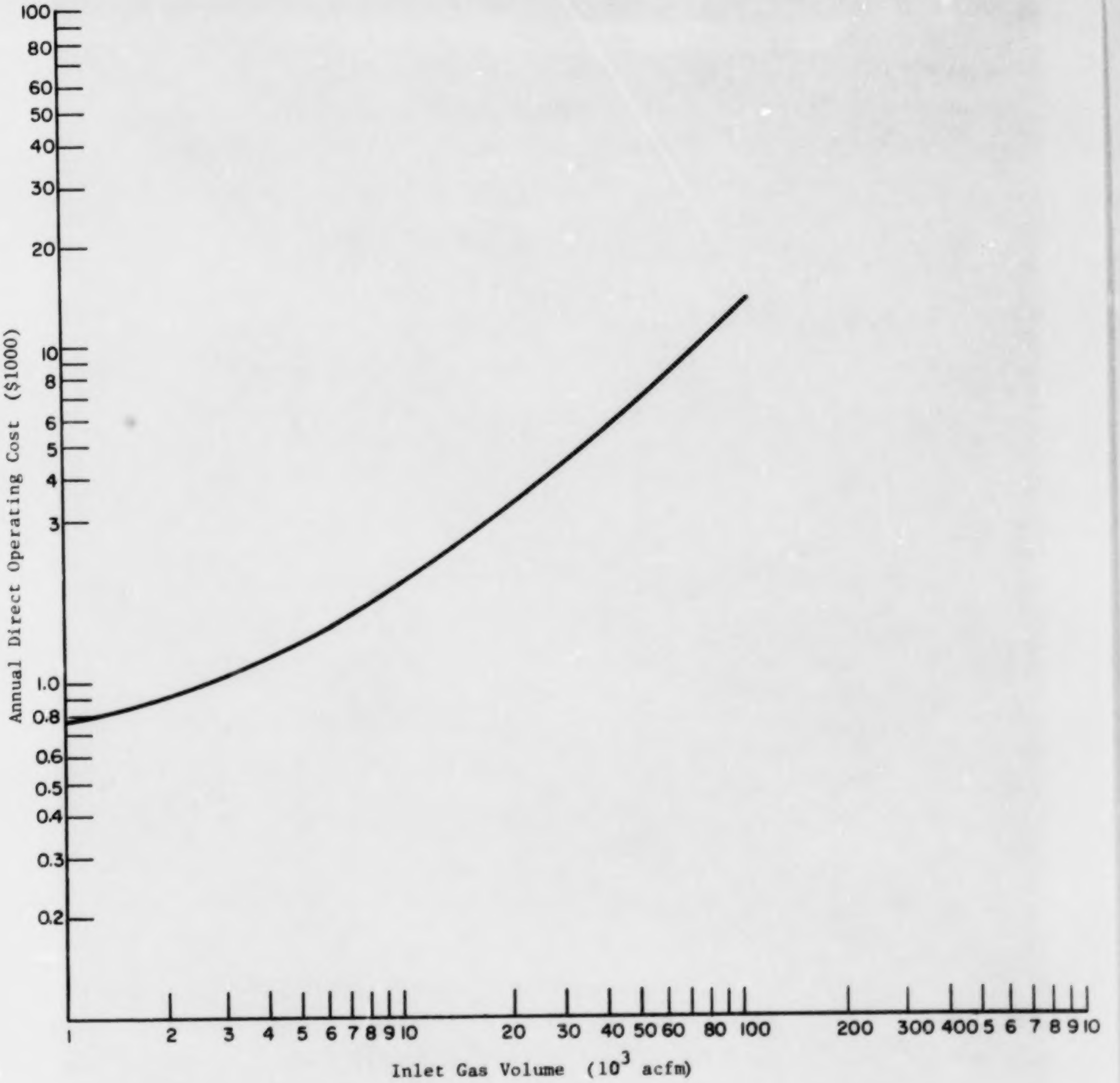
Source: Poly Con Corporation.

Fig. S-3. Annual Direct Operating Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. S-4. Equipment Cost for Cyclonic Scrubbers.



Source: Poly Con Corporation.

Fig. S-5. Annual Direct Operating Cost for Cyclonic Scrubbers.

The distribution of capacities according to manufacturer's reports of rotary kilns and other data were used to calculate a weighted average cost of control per ton of capacity using the data in Table S-3. For rotary kilns, the weighted average installed cost was $73.30 per ton of capacity per day, the weighted average annual cost was $66.20 per ton of capacity per day.

Table S-3

ROTARY LIME KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Number of Kilns	Installed Cost ($1000)	Annual Cost ($1000)
100	4	14.0	8.8
150	3	17.3	12.0
200	16	20.0	15.0
250	8	22.5	17.7
300	10	25.0	20.5
350	9	26.5	23.4
400	14	28.0	26.5
450	4	29.7	29.2
500	18	32.0	31.4
550	6	34.6	34.3
600	2	37.8	37.6
650	4	40.9	41.2
700	2	44.0	45.2

Since data were not available on the capacity distribution for vertical kilns, the rotary kiln capacities were used to design a known distribution for vertical kilns. The weighted average cost of control per ton of capacity was then calculated using data in Table S-4.

For vertical kilns, the weighted average installed cost was $179.20 per ton of capacity per day and the weighted average annual cost was $64.20 per ton of capacity per day.

Table S-4

VERTICAL LIME KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Number of Kilns	Installed Cost ($1000)	Annual Cost ($1000)
10	4	5.8	2.0
26	3	7.2	2.8
42	16	9.0	3.1
58	8	11.1	3.9
74	10	13.9	4.9
90	9	17.0	6.2
106	14	20.2	7.3
122	4	22.1	8.0
138	18	23.7	8.5
154	6	24.9	9.0
170	2	26.1	9.3
186	4	27.1	9.7
200	2	28.0	10.0

To get the overall average cost per ton of capacity, the two average costs were combined using the known production ratio of 80 percent for rotary and 20 percent for vertical kilns. This cost was multiplied by estimated metropolitan area capacity to get the final control costs for each area.

B. Estimated Control Costs

The resulting costs, which take into account existing controls on rotary kilns, were totalled for the 100 metropolitan areas and are shown in Table S-5. Annual control costs would average $0.05 per ton of capacity.

The annual emission of particulates will be reduced from over 251 thousand tons to approximately 25 thousand tons by 1975. Total investment cost will amount to $0.9 million with an ultimate annual cost of $1.4 million.

Table S-5

LIME PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	251	--	--	--	60.0	--	--	--						
FY71	242	--	--	--	61.4	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1
FY72	192	--	--	--	69.2	--	--	--	0.1	0.2	0.3	0.1	0.1	0.2
FY73	106	--	--	--	83.2	--	--	--	0.2	0.3	0.4	0.2	0.3	0.4
FY74	45	--	--	--	92.8	--	--	--	0.1	0.2	0.3	0.3	0.4	0.6
FY75	25	--	--	--	96.0	--	--	--	0.1	0.1	0.1	0.3	0.5	0.7
Total -									0.5	0.9	1.2	1.0	1.4	2.0

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing production (1967) but also for increased production in the lime industry beyond the base year. The projected growth-related air pollution control costs were based on the average overall particulate control level of 96 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth. Based primarily on information received from the National Lime Association, an expected annual production growth rate of two percent per year was chosen. Incremental capacity estimates were based on achieving 90 percent utilization of capacity by 1975. The results of the cost analysis of controlling the new capacity are shown in Table S-6. As shown, the cost in each year reflects immediate control of the incremental capacity at ultimate control levels. Without the act in effect, emissions from the 100 areas from 1967 capacity plus the additional capacity added after 1967 would reach 289 thousand tons by 1975. With the act in effect, emissions would be reduced to 29 thousand tons.

Table S-6

LIME PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (1000 tons/ year)	ADDITIONAL PRODUCTION (1000 tons/ year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	100	536	1.76	--	--	--	--	--	--	--	--	--
FY72	128	689	2.26	--	--	--	--	--	--	--	--	--
FY73	157	842	2.76	--	--	--	--	--	--	--	--	--
FY74	185	996	3.26	--	--	--	--	--	--	--	--	--
FY75	213	1150	3.77	--	--	--	--	--	--	--	--	--
Totals -							--	--	--	--	.1	.1

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix T

Coal Cleaning Industry
(SIC No. 1211)

Appendix T

Coal Cleaning Industry

I. INTRODUCTION

Coal cleaning is the process by which undesirable materials are removed from both bituminous and anthracite coal. This analysis deals only with coal cleaning, not other related operations such as coal crushing, screening, or sizing. Cleaning is accomplished by washing the coal with water or air; if water is used, drying is required.

There are three major sources of air pollution in coal cleaning plant operations--flash driers, fluidized-bed driers, and pneumatic cleaners. Particulates in the form of dust constitute the major air pollution problem in the industry.

In 1967, the 691 coal cleaning plants in the United States had a capacity of 350.0 million tons with a production of 349.0 million tons. Value of shipments amounted to $1.5 billion. The 109 plants in the 100 areas had a capacity of 61.4 million tons and production was about 61.3 million tons. Value of shipments was approximately $0.3 billion. Particulate emissions were 160 thousand tons and 27 thousand tons for the United States and the 100 areas, respectively.

II. CONTROL OF EMISSIONS

The best information at present indicates that about 87 percent of all thermal driers (flash and fluidized-bed) are controlled at a level of 80-percent efficiency; 16 percent of the pneumatic cleaners are also controlled at an 80-percent level. The composite level of control is about 58 percent.

Control costs were estimated for the installation and operation of gas-cleaning equipment that would increase the industry's overall collection efficiency to 95 percent. Such an increase would upgrade the control of particulates to meet the process weight rate regulation used in this analysis.

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III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering approach to estimating control costs for the coal industry consisted of: (a) an evaluation of production processes within the industry, (b) an analysis of uncontrolled emission rates, present levels of control, and the final level required by the standards adopted for this study, and (c) the selection of the most satisfactory control systems to achieve the final control level.

Coal is cleaned by both wet and dry methods. In this analysis three processes within the coal cleaning industry were considered: flash and fluidized-bed thermal driers (for coal cleaned by wet methods), and pneumatic cleaners. These three processes are significant sources of particulate emissions mostly in the form of coal dust. Uncontrolled particulate emission rates from these three processes are shown in Table T-1.

Table T-1

UNCONTROLLED PARTICULATE EMISSION RATES FROM COAL CLEANING PROCESSES[a]

Process	Uncontrolled Emissions (lb/ton coal feed)
Flash drier	12
Fluidized-bed drier	13
Pneumatic cleaner	3

[a] A cyclone is assumed part of process equipment, not air pollution control equipment.

Source: Reference 1 and calculated from data given in References 2 and 3.

Available data on the current level of control reveal that 87 percent of both types of thermal driers and 16 percent of pneumatic cleaners are controlled at an efficiency of 80 percent [Ref. 4]. The composite level of control was about 58 percent, when the processes were weighted according to the quantity of coal handled. To comply with the process weight rate standard assumed in this analysis, flash driers, fluidized-bed driers, and pneumatic cleaners will have to be controlled to efficiencies of 93.2, 97.8, and 94.5 percent, respectively.

The model processes considered in this analysis have the following sizes: flash drier, 50 tons of coal feed per hour; fluidized-bed drier, 208; and pneumatic cleaner, 70 [Refs. 2 and 5]. The gas volumes (control system sizes) are 27, 99.9, and 25 thousand actual cubic feet per minute for the flash drier, the fluidized-bed drier, and the pneumatic cleaner, respectively [Refs. 2,3,5]. The gas stream temperature assumed for this analysis was 159° F [Ref. 5]. The annual hours of operation were 3,750, assuming 2 shifts per day, 7.5 effective hours per shift, 5 days per week, and 50 weeks per year [Ref. 6].

Due to the considerable fire and explosion hazard associated with coal dust, wet scrubbers instead of baghouses are preferred as control devices [Refs. 5,7]. A 16" w.g. venturi scrubber was assumed as the control device for the fluidized-bed drier and a 5" w.g. venturi was assumed for both the flash drier and the pneumatic cleaner. These pressure drops correspond to the required control efficiencies stated above.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Costs estimates for controlling emissions from coal cleaning establishments were based on the types of processes and on the production [Ref. 8] in each metropolitan area. Output or production of total coal cleaned was prorated to the different processes as follows: 7.1 percent by pneumatic methods with the remainder to wet washing. Nationally, only 20.7 percent of cleaned coal is thermally dried and 43.5 percent of thermally dried coal is dried in fluidized-bed driers [Ref. 9]. The remaining 56.5 percent of thermally dried coal was assumed to be dried in flash driers. As appropriate, state data on the percent of cleaned coal that is thermally dried were used [Ref. 9].

Number of plants is not known; however, metropolitan area capacity was obtained [Ref. 1]. Therefore, only a model plant approach could be used. Because of the coal dust content of the off-gases and the consequent explosion potential, wet scrubbers constructed of mild steel were selected as the gas-cleaning device. Data from the PolyCon Corporation [Ref. 10] were used to develop unit costs for the model plant and derive investment and annual costs per ton of coal cleaned for control of emissions.

Cost estimating factors were calculated separately for pneumatic cleaners, fluidized-bed driers, and flash driers (see Table T-2). The cost factors then were applied to the estimated capacity by process type in each area.

Table T-2

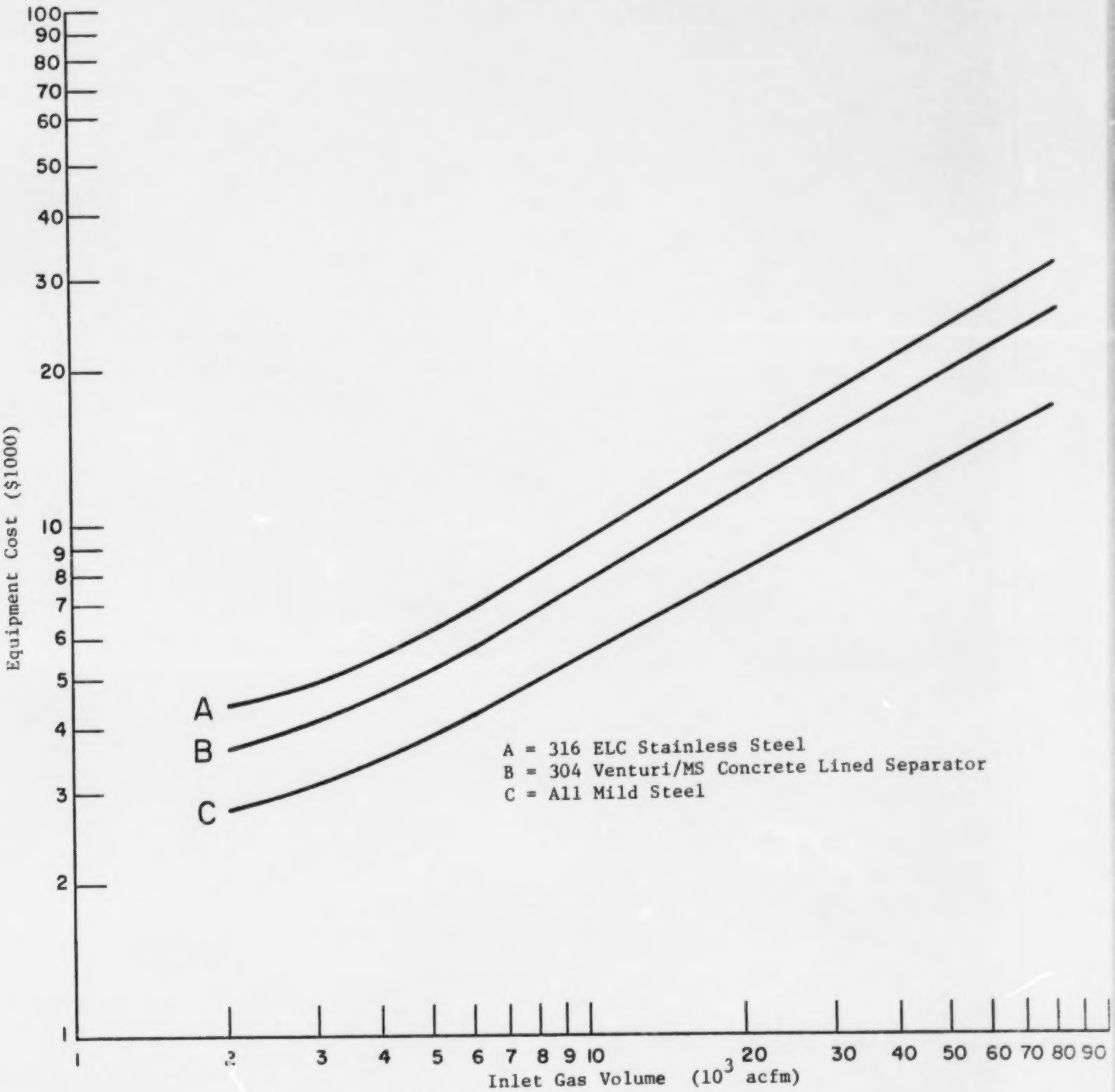
COAL CLEANING EMISSION CONTROL COSTS

Equipment Type	Costs ($1000/ton/hour	
	Investment	Annual
Pneumatic cleaners	0.316	0.107
Fluidized-bed driers	0.247	0.098
Flash driers	0.463	0.158

B. Estimated Costs

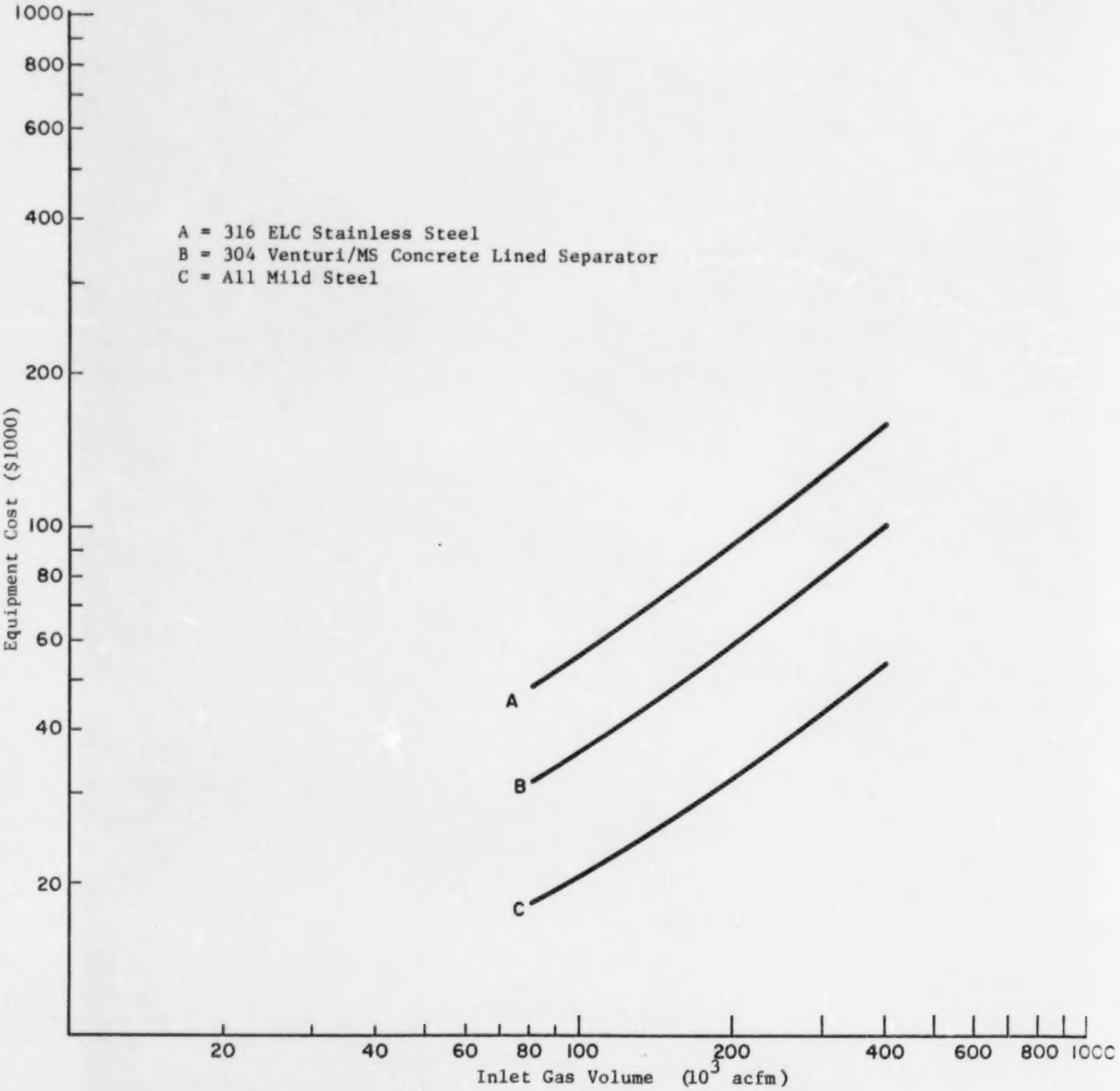
The resulting costs, which include credits for existing controls, were totalled for the 100 metropolitan areas and are shown in Table T-3. Control costs would average approximately $0.01 per ton of coal cleaning capacity when the plan is fully implemented.

The emission of particulates in the 100 areas would be reduced from over 27 thousand tons in 1967 to approximately 3 thousand tons by 1975. The investment cost for this level of control would total $1.5 million, with an ultimate annual cost of $0.5 million.



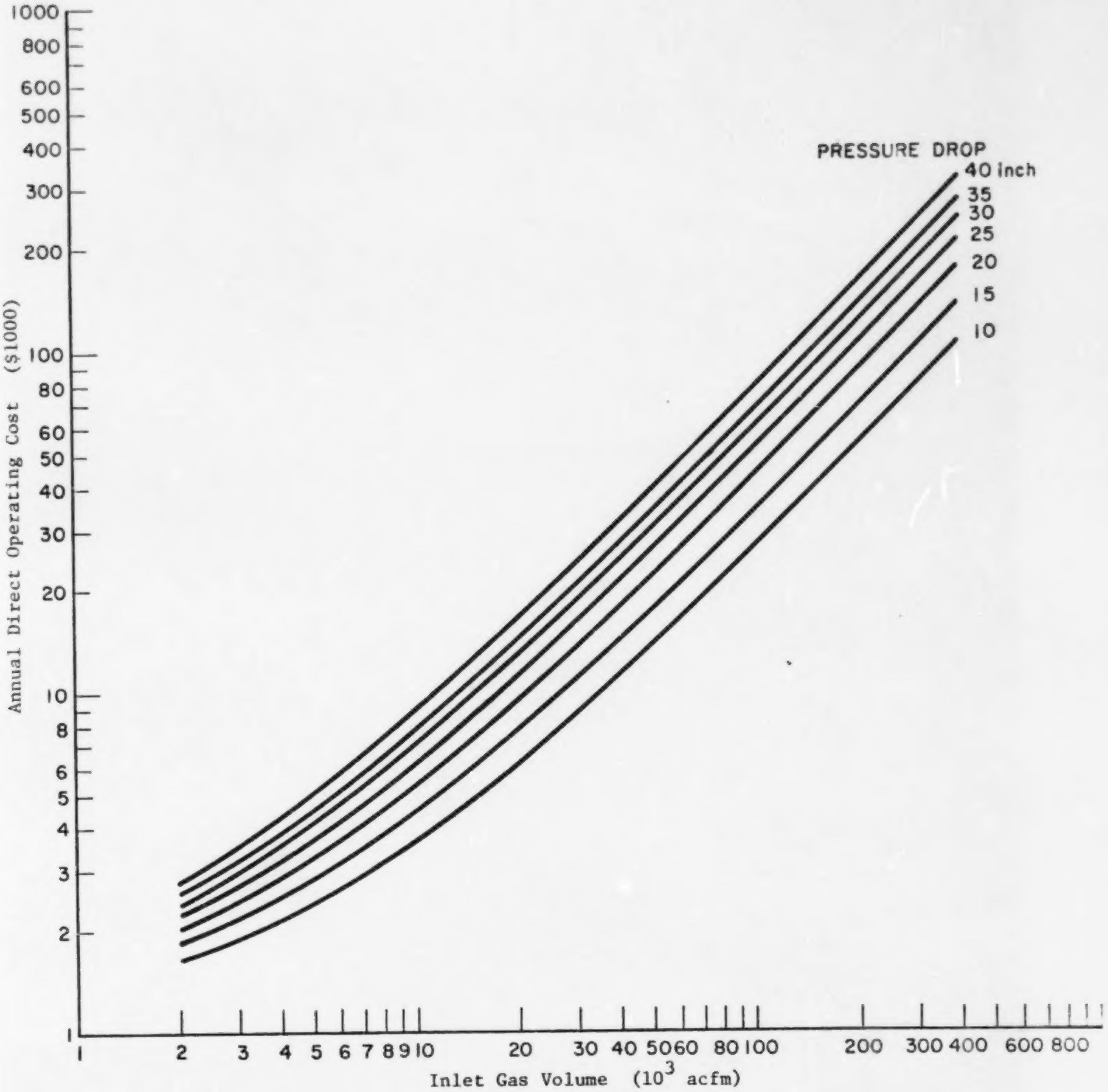
Source: Poly Con Corporation.

Fig. T-1. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. T-2. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. T-3. Annual Direct Operating Cost for Venturi Scrubbers.

Table T-3

COAL CLEANING PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	27	--	--	--	57.5	--	--	--						
FY71	26	--	--	--	59.3	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1
FY72	20	--	--	--	67.8	--	--	--	0.2	0.4	0.5	0.1	0.2	0.2
FY73	12	--	--	--	81.2	--	--	--	0.3	0.5	0.8	0.2	0.3	0.5
FY74	6	--	--	--	90.3	--	--	--	0.2	0.3	0.5	0.2	0.5	0.7
FY75	3	--	--	--	94.6	--	--	--	0.1	0.2	0.3	0.3	0.5	0.8
Total -									0.9	1.5	2.2	0.9	1.6	2.3

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity but also for projected increased capacity in the coal cleaning industry. The projected growth costs were based on the required ultimate control level for the industry. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth. An average annual growth rate of production of ten percent per year is expected for the period. The capacity estimates were derived from the production estimates and based on achieving 90 percent utilization of capacity by FY 1975. Cost estimates for controlling emissions from production added after 1967 are shown in Table T-4. By 1975, the 1967 capacity plus the capacity added after 1967 would result in emissions in the 100 areas of 47 thousand tons of particulates without the act in effect; with the act in effect, emissions would be reduced to 5 thousand tons.

Table T-4

COAL CLEANING PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr.)	ADDITIONAL PRODUCTION (thousand tons/yr.)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	27,000	21,500	1	--	--	--	0.1	0.2	0.3	0.1	0.1	0.1
FY72	34,700	27,600	1	--	--	--	0.1	0.2	0.4	0.1	0.1	0.2
FY73	42,400	33,700	1	--	--	--	0.1	0.3	0.4	0.1	0.2	0.4
FY74	50,100	39,800	2	--	--	--	0.1	0.2	0.4	0.2	0.3	0.5
FY75	57,800	46,000	2	--	--	--	0.1	0.2	0.3	0.2	0.4	0.6
Totals -							0.5	1.1	1.8	0.7	1.1	1.8

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix U

Petroleum Products Storage Industry
(SIC No. 5092)

Appendix U

Petroleum Products Storage Industry

I. INTRODUCTION

Principal types of wholesale petroleum and petroleum storage establishments are: (a) petroleum bulk stations and terminals, (b) liquified petroleum gas terminals, (c) crude oil wholesalers, and (d) packaged petroleum products wholesalers.

In 1967, a national total of 29,664 plants had a storage capacity of 7.8 billion gallons of gasoline and handled about 58.6 billion gallons. Value of shipments amounted to $17.5 billion. Capacity was about 5.1 billion gallons for the 6,130 plants located in the 100 metropolitan areas. The gasoline handled amounted to 32.8 billion gallons and value of shipments amounted to approximately $9.8 billion.

The only significant emissions are hydrocarbons evaporated during storage in fixed roof tanks and during transfer operations. For 1967, uncontrolled emissions amounted to 1,100 thousand tons of hydrocarbons in the United States and 636 thousand tons in the 100 metropolitan areas.

II. CONTROL OF EMISSIONS

Seventy-five percent of all storage tanks have floating roofs and about 50 percent of the terminals use submerged or bottom-fill transfer techniques which substantially decrease hydrocarbon emissions. Floating roofs in storage tanks control evaporation by about 90 percent, whereas submerged filling during transfer operations eliminates about 40 percent of potential emissions. The current overall control level for storage and transfer is about 53.5 percent.

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The standard for hydrocarbon emission control used in this study requires that storage tanks be equipped with floating roofs or equally effective devices. Gasoline storage tanks require submerged filling inlets. The application of these devices to all uncontrolled tanks would result in overall control of 75 percent.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ANALYSIS

A. Cost Data

Costs for converting fixed-roof storage tanks to floating roof tanks are shown in Figure U-1. Costs for submerged fill techniques were not readily available; however, these techniques usually require only a modified nozzle on the hose used to fill tank trucks, and a length of pipe attached to the inside of the tank for submerged tank filling; the costs for such are minimal. Complete gasoline emission loading systems utilizing vapor recovery would, of course, cost much more.

B. Emission Data

The factors used to determine emissions from bulk gasoline storage [Ref. 1] are presented in Table U-1.

Table U-1

EMISSION FACTORS FOR BULK GASOLINE STORAGE

Process	Emission Factors	
	Uncontrolled	Controlled
Storage losses	47 lbs/day/1000 bbl	4.7 lbs/day/1000 bbl
Tank filling	8.2 lbs/1000 gal	4.9 lbs/1000 gal
Truck filling	11.5 lbs/1000 gal	6.9 lbs/1000 gal

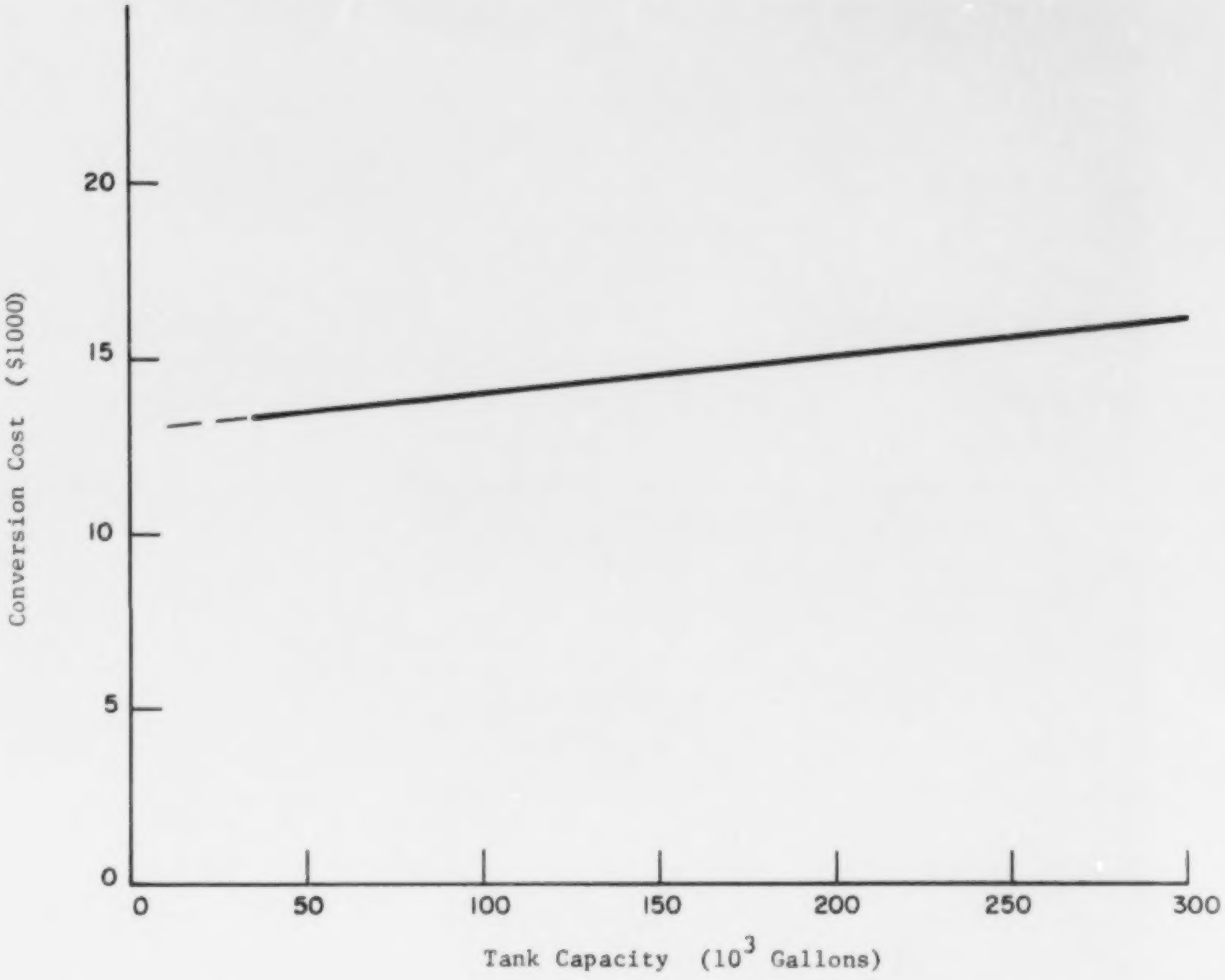

Fig. U-1. Cost for Converting Fixed-Roof Gasoline Storage Tanks to Floating Roof Tanks.

Transfer losses were based on ten full turnovers in tank contents per year; which was estimated by dividing total volume of gasoline sold by total gasoline storage capacity. To determine total metropolitan area emissions, three-fourths of all tanks were assumed to have floating roofs, and one-half of all transfer operations used submerged fill techniques [Ref. 1].

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

While the costs for converting a specific sized, fixed-roof gasoline storage tank to a floating roof tank were fairly well known, the distribution of tank sizes within any area was not known. A model tank approach was therefore used to estimate tank conversion costs for the various areas. The model tank size selected was 290 thousand gallons based on the fact that an average bulk gasoline storage facility has a capacity of 2.9 million gallons, assuming 10 turnovers per year. This was calculated using the present estimated national capacity of 8.8 billion gallons and approximately 30 thousand storage facilities. Seventy-five percent of all gasoline storage tanks were assumed to be presently controlled except for California which has 100 percent control.

The cost for converting a model-sized tank with a capacity of 290 thousand gallons from a fixed-roof to a floating roof unit was estimated to be $16 thousand as shown in Figure U-1. Costs for smaller sized tanks were also taken from Figure U-1 and were used to estimate the costs for the remaining storage capacity not accounted for by an even number of model tanks. Thus, in any given area, the average capacity of each establishment was determined (total area capacity [Ref. 3] divided by number of establishments [Ref. 3]); the equivalent number of model tanks within each average establishment was then obtained (average capacity divided by 290 thousand gallons) and costed at $16 thousand each; the remaining capacity was then costed as a separate item and added to the cost of the model plants. This total cost was then multiplied by one-fourth of the number of establishments to arrive at the total area cost; this takes into account the estimate that 75 percent are already controlled.

It was assumed that all plants would prefer converting their uncontrolled tanks to floating roof units to the alternative of installing new tanks. The cost for installing submerged filling equipment was included in the cost of converting the tank.

Annualized costs were not included since the amount of gasoline saved will usually more than cover the annualized expenses incurred in converting the tank.

B. Estimated Costs

The resulting investment costs, which include allowance for existing controls, were totalled for the 100 metropolitan areas; these are shown in Table U-2. The emission of hydrocarbons would be reduced from over 635 thousand tons in 1967 to approximately 343 thousand tons by 1975. The investment cost for this level of control would total over $68.2 million; however, there would probably be no or very small annual costs due to the reduction of product losses.

V. CONTROL COSTS RESULTING FROM GROWTH

In addition, air pollution control costs were calculated for projected increased capacity in the petroleum products storage industry after the base year of 1967. The projected growth costs were based on the expected ultimate control level of 75.0 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth. An average annual growth rate of 3.0 percent in gasoline production and therefore new storage capacity was assumed for the period 1967 to FY 1975 [Ref. 4]. The estimated costs of controlling the projected additional capacity are shown in Table U-3. As shown, costs in each year reflect the installation of floating roof tanks. By 1975, without the act, hydrocarbon emissions in the 100 areas would reach 779 thousand tons for the 1967 capacity plus the capacity added after 1967. With the act in effect, emissions would be reduced to 419 thousand tons.

Table U-2

PETROLEUM PRODUCTS STORAGE PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	--	--	636	--	--	--	53.5	--						
FY71	--	--	636	--	--	--	53.5	--	0.0	0.0	0.0	0.0	0.0	0.0
FY72	--	--	586	--	--	--	57.0	--	9.2	11.5	14.9	0.0	0.0	0.0
FY73	--	--	493	--	--	--	64.0	--	22.2	27.7	36.1	0.0	0.0	0.0
FY74	--	--	374	--	--	--	73.0	--	17.4	21.7	28.2	0.0	0.0	0.0
FY75	--	--	343	--	--	--	75.0	--	5.7	7.1	9.3	0.0	0.0	0.0
Total -									54.5	68.0	88.5	0.0	0.0	0.0

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table U-3

PETROLEUM PRODUCTS STORAGE PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (million gallons storage)	ADDITIONAL PRODUCTION (million gallons per year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	541	3,530	--	--	35	--	1.6	2.1	2.7	0.0	0.0	0.0
FY72	695	4,430	--	--	45	--	2.3	2.9	3.8	0.0	0.0	0.0
FY73	850	5,410	--	--	56	--	3.3	4.2	5.5	0.0	0.0	0.0
FY74	1,000	6,390	--	--	66	--	3.0	3.7	4.9	0.0	0.0	0.0
FY75	1,160	7,380	--	--	76	--	2.1	2.6	3.4	0.0	0.0	0.0
Totals							12.3	15.5	20.3	0.0	0.0	0.0

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix V

Grain Milling and Handling Industry
(SIC No. 204X)

Appendix V

Grain Milling and Handling Industry

I. INTRODUCTION

Commercial grain mills process grain into flour, livestock feeds, cereals, corn syrup, and various bread and pastry mixes. Grain elevators provide storage space and serve as collection and transfer points.

In 1967, there were 2,866 grain mills in the Nation, with 907 of these located in the 100 areas. National capacity and production were 64.0 million tons and 50.5 million tons, respectively; capacity and production for the 100 areas were 43.9 million tons and 35.5 million tons, respectively. Value of shipments was $4.6 billion for the Nation and $3.7 billion for the 100 areas.

The 11,147 grain elevators in the United States had a capacity of 5.5 million bushels, and production (throughput) was about 18.0 million bushels. Capacity and production for the 1,089 elevators in the 100 areas was 1.3 million bushels and 4.4 million bushels, respectively.[1/]

Dusts are generated in both the milling operations in grain mills and the handling and cleaning of grain in elevators; however, large dust particles are generally controlled. In the milling of products other than livestock feed, fine dusts are also controlled because of their value. Estimates are presented in this report for the milling operation in livestock feed mills and the cleaning and handling operations in terminal grain elevators. Terminal elevators contribute the vast majority of the particulate emissions from the grain milling and handling industry and nearly all terminal elevators in the United States are located in the 100 metropolitan areas. In 1967, total particulate emissions from livestock feed mills and elevators were about 1210 thousand tons for the Nation and 1200 thousand tons for the 100 areas.

[1/] Value of shipments is not applicable.

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II. CONTROL OF EMISSIONS

Control of dust emitted from livestock feed milling and handling can be accomplished with air-cleaning devices, such as fabric filters, to give 99 percent or better control as compared to the present average control level of 35 percent. Such controls will bring the level of emission into compliance with the process weight rate regulation for particulate control.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATION

The basic engineering approach taken in order to estimate air pollution control costs for grain mills and elevators consisted of: (a) an attempt to determine the number and size of all grain mills and elevators in the United States, (b) estimating the total amount of grain processed in the United States, (c) estimating the operations through which an "average grain" passes from field to final product, and (d) determining the quantities of dust generated during each of the elevator and milling operations. Since only dusts are generated during these operations, and considering the nature of the industry, the preferred control systems were cyclones plus fabric filters. Use of these is adequate to reduce emissions to acceptable levels.

Determining the number of grain elevators and mills in the United States was difficult because of differing opinions as to what constitutes an elevator and lack of accurate census data for elevators and mills. The estimates used in this study came from a U.S. Department of Agriculture listing of warehouses approved to handle grain under the Commodity Credit Corporation agreements [Ref. 1]. Since all elevators and mills are not parties to these agreements, it has been estimated that only 85 percent of total storage capacity is accounted for in this listing [Ref. 2].

The grain from field to consumer goes through many processes; moreover, different grains receive different treatment during the processing steps. To simplify calculations, all grain was assumed to proceed through the following steps: (a) after harvesting, the grain is taken to a country elevator; (b) there it is unloaded, weighed, and stored for an indefinite period; (c) it is then loaded into a type of conveyance and taken to a terminal elevator; and (d) it is then unloaded, weighed again, given a preliminary cleaning, and again stored for an indefinite period.

During storage at the terminal elevator, some of the grain must be "turned" or "transferred" -- that is, transferred from one bin to another, usually for the purpose of reducing its temperature which has been slowly increasing due to any of several biochemical reactions. Also, it was estimated that 80 percent of all corn is dried mechanically at terminal elevators [Ref. 3]. It was further assumed that all grains in terminal elevators are either exported or processed into animal feeds, with the exception of wheat. Seventy-five percent of the wheat in this country is milled into flour for human consumption.

Dust generated during most of these processing steps results principally from mechanical abrasion of the individual grains. Best estimates of the quantities of dust generated during each step have been obtained from two experiments [Refs. 3, 4, and 5], but even these must be considered only approximations because of the experimental difficulties involved. The overall emission factors selected on the basis of these studies are 19.1 pounds of particulate per ton of grain for grain handling at terminal elevators, and 6.0 pounds of particulate per ton of grain processed for grain milling for the production of animal feed.

It has been assumed further that few, if any, country elevators are equipped with dust control devices. This is not necessarily important in this study, however, since few country elevators are within the 100 metropolitan areas. In contrast nearly all terminal elevators are located in the 100 metropolitan areas. Only 50 percent of terminal elevators and animal feed mills are assumed to be equipped with cyclones, which remove only 70 percent of the dust conveyed to them [Ref. 3]. Fabric filters will be required to reduce the remaining dust emissions to acceptable levels. Calculations of costs to equip the elevators with cyclones and baghouses were based partly on an assumed minimum air velocity (3500 ft/min) required to prevent dust settling in horizontal ducts, the size of ducts for small installations (6 inches in diameter), and the detailed equipment cost analyses presented in Figure V-1. It was assumed that all wheat flour mills are equipped with fabric filters and that the dust emissions from baghouse exhausts meet the proposed process weight rate standard.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

1. Grain Elevators

A list of grain elevators by counties was obtained [Ref. 7] and data were classified by employment size category as shown in Table V-1.

Table V-1

EMPLOYMENT SIZE CATEGORY FOR GRAIN ELEVATORS

Employment Size Category	Capacity (tons/day)
0	unknown
1	< 25
2	25-74
3	75-150
4	150-250
5	250-500
6	500-1000
7	1000-2500
8	2500-5000
9	5000-10,000
10	> 10,000

The next step was to compile a distribution of elevator capacities for each metropolitan area. Data concerning total grain handled were used to estimate total industry capacity which was in turn prorated to individual grain elevators on the basis of employment range. For each area, the plants with unknown employment were distributed among the other categories by one of two methods. If an area had a large number of plants already distributed according to employment, the smaller number of unknowns was prorated among the categories according to this distribution. On the other hand, if the majority in an area was unknown, it was distributed in proportion to the distribution for the total known capacities in the 100 metropolitan areas.

Finally, an investment cost for each grain elevator size category was determined. An estimated equipment purchase cost was developed for each size category [Ref. 6]. The sum for each area was multiplied by 1.75 to get the investment costs and by 0.35 to estimate annual costs. These costs are shown in Table V-2. Costs for each area were calculated as the sum of costs for elevators in all size categories.

Table V-2

GRAIN ELEVATOR EMISSION CONTROL COSTS

Size Category	Nominal Capacity (tons/day)	Equipment Costs ($1000)[a]	Investment Costs ($1000)[b]	Annual Costs ($1000)[c]
1	< 25	5.1	8.9	3.1
2	25-74	7.3	12.8	4.5
3	75-150	9.4	16.5	5.8
4	150-250	11.2	19.6	6.9
5	250-500	10.8	18.9	6.6
6	500-1000	12.0	21.0	7.4
7	1000-2500	13.6	23.8	8.3
8	2500-5000	15.2	26.6	9.3
9	5000-10,000	16.6	29.1	10.2
10	> 10,000	18.5	32.4	11.3

[a] Equipment costs are for multicyclones followed by baghouses. Cyclones are assumed to be already installed on elevators of Category 5 and higher.

[b] Investment costs calculated at 1.75 times equipment costs.

[c] Annual costs calculated at 0.35 times investment costs.

2. Grain Mills (Livestock Feed)

A listing of livestock feed mills and the number of employees at each mill was obtained from Dun and Bradstreet data. Capacities (tons/day) for each area in 1963 [Ref. 8] were scaled upward to 1967 by using the 1967 to 1963 ratio of high protein feed, which comprises the major proportion of all livestock feed. The area capacities were then prorated to individual plants according to the number of employees at each plant.

Costs for each mill were estimated on the basis of three operations per plant: loading, transferring and handling, and cleaning. Cleaning was included only for plants producing less than 615 tons a day; larger mills are reported not to clean grain. Gas volumes were calculated for each process, and seven sizes of fabric filter systems were assigned according to the estimated gas volume.

Purchase cost for fabric filters as a function of gas flow is shown in Figure V-1. Installation costs were estimated at 1.75 times the purchase cost, and annual costs as 0.35 times the investment cost. The resulting process size relationships are presented in Table V-3.

Table V-3

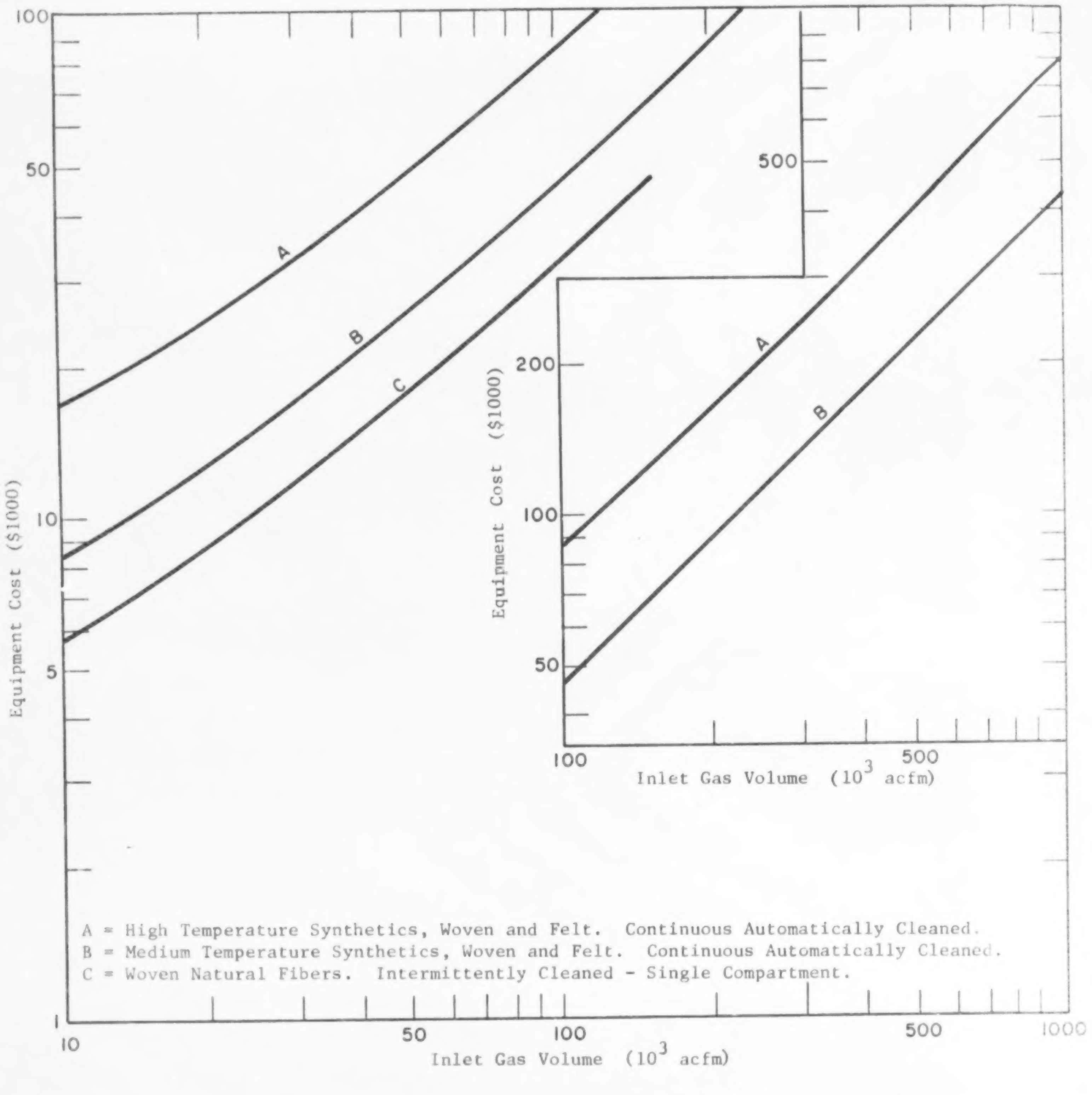
LIVESTOCK FEED MILL EMISSION CONTROL COSTS

Mill Capacity (tons/day)	Equipment Costs ($1000)			Total Costs ($1000)	
	Unloading	Transferring & Handling	Cleaning	Investment[a]	Annual[b]
10.3	4.0	5.5	4.0	23.6	8.26
30.8	4.3	6.2	5.5	28.0	9.80
71.8	4.6	6.8	8.8	35.4	12.40
154.0	4.6	6.8	15.4	46.6	16.30
615.0	4.6	6.8	0.0[c]	20.0	7.00
1538.0	5.3	8.2	0.0[c]	23.6	8.26
2563.0	7.2	11.9	0.0[c]	33.4	11.70

[a] Investment cost calculated at 1.75 times total equipment costs.

[b] Annual cost calculated at 0.35 times total investment cost.

[c] No grain cleaning in plants of these sizes.



Source: Edmisten, N. G. and F. L. Bunyard, "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources." Presented at the annual meeting of the Air Pollution Control Association, New York, June 1969.

Fig. V-1. Equipment Cost of Fabric Filters.

B. Estimated Control Costs

The resulting costs that take into account existing cyclone collectors were totalled for the 100 metropolitan areas and are shown in Tables V-4 and V-5. Annual control costs would average $0.01 per bushel of storage capacity and approximately $0.18 per ton of animal feed mill capacity.

Emissions of particulates would be reduced from 1.1 million tons per year to 17 thousand tons per year for grain elevators and from 96 thousand to 1 thousand tons per year for animal feed mills when the plan is fully implemented. Total investment costs would amount to $21.3 million for grain elevators and $22.1 million for animal feed mills. Annual costs would reach $7.5 million for the elevators and $7.8 million for the animal feed mills by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing elevator storage capacity but also for increased capacity beyond the base year of 1967. Present (1967) capacity for animal feed milling is considered adequate to 1975. The projected costs were based upon the required ultimate control level of 99 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth. A growth rate of 1.5 percent per year was selected based primarily upon information included in Resources in America's Future [Ref. 9]. The capacity estimates were based on maintaining the same capacity - production relationship that existed in the 1967 base year.

The results of the cost analysis are shown in Table V-6. Costs reflect immediate control of the incremental storage capacity at the ultimate control efficiency. By 1975, for the 1967 capacity plus the capacity added after 1967 without the act in effect, particulate emissions for mills and elevators in the 100 areas would reach 1350 thousand tons; while with the act in effect, these emissions would be reduced to 20 thousand tons.

Table V-4
GRAIN ELEVATORS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	1100	--	--	--	35.0	--	--	--						
FY71	1078	--	--	--	36.3	--	--	--	0.3	0.5	0.7	0.1	0.1	0.2
FY72	858	--	--	--	49.3	--	--	--	2.6	4.0	5.4	1.0	1.5	2.1
FY73	443	--	--	--	73.8	--	--	--	5.2	8.0	10.8	2.8	4.3	5.9
FY74	143	--	--	--	91.5	--	--	--	4.1	6.4	8.7	4.3	6.6	8.9
FY75	17	--	--	--	99.0	--	--	--	1.6	2.4	3.3	4.8	7.5	10.1
Total -									13.8	21.3	28.9	13.0	20.0	27.2

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table V-5

GRAIN MILLS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	96	--	--	--	35.0	--	--	--						
FY71	91	--	--	--	38.6	--	--	--	0.5	1.0	1.5	0.1	0.3	0.5
FY72	68	--	--	--	53.7	--	--	--	2.4	4.8	7.2	1.0	2.0	3.0
FY73	39	--	--	--	73.3	--	--	--	4.0	7.9	11.9	2.4	4.9	7.4
FY74	10	--	--	--	93.0	--	--	--	2.9	5.9	8.8	3.5	7.0	10.5
FY75	1	--	--	--	99.0	--	--	--	1.2	2.5	3.7	3.9	7.8	11.8
Total -									11.0	22.1	33.1	10.9	22.0	33.2

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

Table V-6

GRAIN ELEVATORS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (million bushels storage space)	ADDITIONAL PRODUCTION (million bushels/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	70	230	1	--	--	--	0.2	0.3	0.4	0.1	0.1	0.2
FY72	90	296	1	--	--	--	0.3	0.4	0.6	0.2	0.3	0.4
FY73	110	362	2	--	--	--	0.4	0.6	0.8	0.3	0.5	0.7
FY74	130	428	2	--	--	--	0.3	0.5	0.7	0.5	0.7	0.9
FY75	150	494	2	--	--	--	0.2	0.4	0.5	0.6	0.9	1.1
Totals -							1.4	2.2	3.0	1.7	2.5	3.3

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix W

Varnish Industry
(SIC No. 2851)

Appendix W

Varnish Industry

I. INTRODUCTION

Varnish production, unlike that of paint and lacquer, involves a cooking process which results in the evaporation and emission of hydrocarbons. In 1967 there were 230 varnish plants in the United States; 216 of the U.S. total were in the 100 metropolitan areas. National capacity and production were estimated at 56.0 million gallons and 45.4 million gallons, respectively. National value of shipments amounted to $0.1 billion. In the 100 areas, capacity and production were estimated at 52.0 million gallons and 43.0 million gallons, respectively and value of shipments approached $0.1 billion.

II. CONTROL OF EMISSIONS

All varnish plants in California were assumed to be controlled, while only about 20 percent of the plants located elsewhere were assumed to be controlled. Those controlled by afterburners were assumed to have an efficiency of 90 to 95 percent. The overall national level of control was estimated to be 18 percent. To meet the standards selected for this report, varnish plants need to reduce the organic content of the effluent gas stream by 90 percent.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ESTIMATES

The cost of a direct-fired afterburner system serving two varnish cookers varies from about $2,000 to $3,000 depending on the type of venting system and the exact type of afterburner [Refs. 1,2, and 3]. Exit gas rates on the order of 350 acfm to about 1,000 acfm are normally encountered. More than one varnish cooker is usually used at a plant, and for the

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purposes of this report, a step-wise increase in cost was used as the manufacturing capacity at an establishment increased. This cost versus size relationship is shown in Figure W-1.

Operation and maintenance costs, assuming gas stream input and output temperatures of 500° and 1200° F, respectively, were based on the following equation:

$$G = S[195.5 \times 10^{-6} PHK + HF_i + M]$$

where: S = acfm, 600 acfm for up to 250 gal tank, and 1200 acfm for 250-1000 gal tank;

P = 1" water;

H = 2400 hours/year (240 days at 10 hrs/day);

K = \$0.01/kw-acfm;

F_1= \$0.0027/acfm-hr (0.03 cfm fuel/acfm exit gas) [Ref. 4], fuel cost = \$0.00015/ft^3;

F_2= \$0.0015/acfm-hr, fuel cost = \$.00085/ft^3;

F_3= \$0.0009/acfm-hr, fuel cost = \$.00050/ft^3;

M = \$0.06/acfm.

The various fuel costs (F_i) were based on average gas rates for different parts of the country [Ref. 5]. Using these fuel costs, the annualized cost factors (including 20 percent depreciation and capital charges) presented in Table W-1 were obtained.

Table W-1

CAPACITY VS. ANNUALIZED COST FACTORS

Capacity (gal)	Annualized Cost Factors ($)		
	East Coast, Northwest, Hawaii	Midwest	Southwest
0-250	4390	2650	1820
250-1000	8705	5225	3365

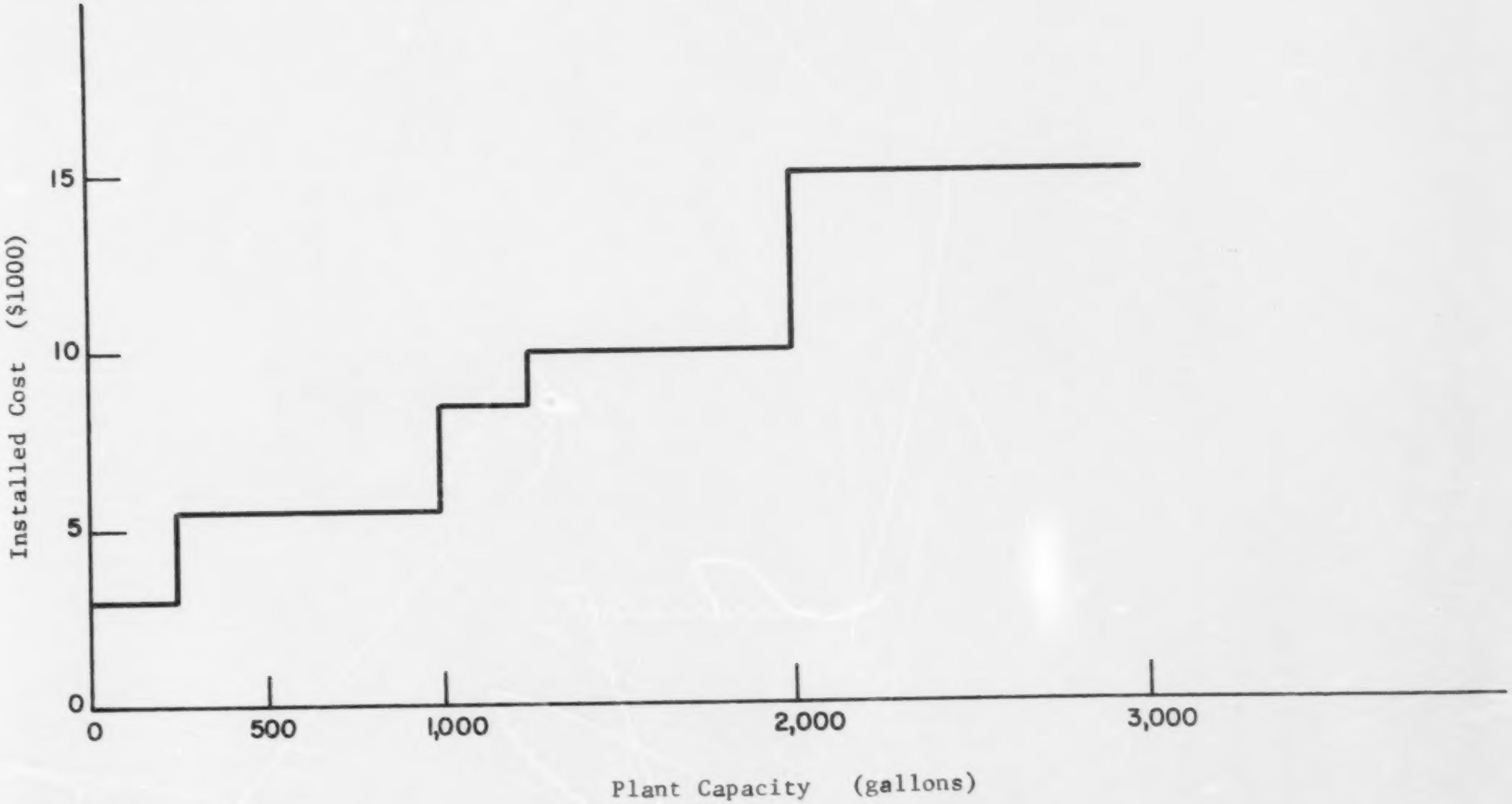

Fig. W-1. Installed Cost for Direct-fired Afterburner for Varnish Plant.

Emissions for 1967 were estimated by using an emission factor of 4 percent of throughput [Ref. 6] and assuming 20 percent of the plants were already controlled. Fully controlled emission estimates were based on all plants being controlled with a hydrocarbon removal efficiency of 90 percent.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Due to the varied types of varnish plants, a model plant approach was used to determine control costs. Plant names, locations, and numbers of employees for plants producing varnish were extracted from a Dun and Bradstreet listing. Area varnish-making capacity was estimated by relating regional employment to the ratio of national production of varnish to national employment in the industry. The control costs for the model plant were based on a production rate of 250 gallons per cooker and on a direct-fired afterburner (without heat exchange) control system. A step-wise increase in control costs based on as many as four tanks venting into a single control system was used. Any plant larger than one thousand gallons (4 cookers at 250 gal. each), therefore, required at least two control systems.

Twenty percent of the plants throughout the country were assumed to have adequate existing controls and all plants in California were assumed to be adequately controlled.

The average size of the plants within a region was obtained by first dividing the annual regional varnish manufacturing capacity by 240 days per year and then dividing this daily capacity by the number of establishments. Where one or two plants in a region were extremely large, as indicated by their employment, they were handled separately, i.e., not averaged in with the smaller plants. Only plants with more than 2 employees were included in the cost analysis.

The cost for the average plant (indicated in Figure W-1) was multiplied by 0.8.[1] Costs for very large plants were estimated as separate items and added to the cost of the average plants.

Annualized costs included operating and maintenance costs and 20 percent of capital investment. Variation in fuel cost was taken into account as previously shown in Table W-1.

B. Estimated Costs

The resulting costs, that take into account that 100-percent of plants are controlled in California and 20-percent are controlled in the rest of the Nation, were totalled for the 100 metropolitan areas and are shown in Table W-2. Control costs would average approximately $0.02 per gallon of varnish-making capacity when the plan is fully implemented.

The emission of hydrocarbons would be reduced from approximately 5 thousand tons in 1967 to approximately 0.1 thousand tons by 1975. The investment cost for this level of control would total $700 thousand with an annual cost of $800 thousand by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for increased capacity estimated to be installed in the varnish industry between 1967 and FY 1975. The projected growth costs were based on the expected ultimate control level of 90.0 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An average annual production growth rate of 5.0 percent was used.[2] The capacity estimates, derived from the production estimates, were based

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[1] Eighty percent of the plants were assumed uncontrolled.

[2] The primary source for this estimate was The National Paint, Varnish, and Lacquer Association.

Table W-2

VARNISH PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	--	--	5	--	--	--	18.0	--						
FY71	--	--	5	--	--	--	18.0	--	0.0	0.0	0.0	0.0	0.0	0.0
FY72	--	--	4	--	--	--	33.9	--	0.1	0.1	0.2	0.1	0.2	0.2
FY73	--	--	2	--	--	--	66.1	--	0.2	0.3	0.5	0.3	0.5	0.7
FY74	--	--	1	--	--	--	85.6	--	0.1	0.2	0.3	0.4	0.7	1.0
FY75	--	--	1	--	--	--	90.0	--	0.1	0.1	0.1	0.4	0.8	1.1
Total -									0.5	0.7	1.1	1.2	2.2	3.0

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

on achieving 90-percent utilization of capacity by FY 1975.

The estimated cost of controlling the additional varnish-making capacity are shown in Table W-3. As shown, costs in each year reflect immediate control of the additional capacity. Without the act, 1975 emissions from the 1967 capacity plus the additional capacity in the 100 areas would reach 6 thousand tons of hydrocarbons annually. With the act in effect, annual emissions would be reduced to less than 2 thousand tons.

Table W-3

VARNISH PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand gallons/yr)	ADDITIONAL PRODUCTION (thousand gallons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	5,600	6,810	--	--	<1	--	0.1	0.1	0.1	0.1	0.1	0.1
FY72	7,200	8,760	--	--	<1	--	0.1	0.1	0.1	0.1	0.1	0.1
FY73	8,800	10,700	--	--	<1	--	0.1	0.1	0.1	0.1	0.1	0.3
FY74	10,400	12,700	--	--	<1	--	0.1	0.1	0.1	0.1	0.2	0.4
FY75	12,000	14,600	--	--	<1	--	0.1	0.1	0.1	0.1	0.3	0.4
Totals -							0.5	0.5	0.5	0.5	0.8	1.3

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix X

Rubber (Tires and Inner Tubes) Industry
(SIC No. 3011)

Appendix X

Rubber (Tires and Inner Tubes) Industry

I. INTRODUCTION

This industry includes establishments primarily engaged in manufacturing pneumatic tire casings, inner tubes, solid and cushioned tires for all types of vehicles, and tire repair and retreading materials. The various operations within the industry emit particulates (mostly carbon black, but also fine dust, fumes, and smoke) and hydrocarbons from cord dipping.

In 1967, there were 159 rubber plants in the United States with a combined capacity of 250.0 million tires and tubes per year. Production was 203.0 million tires and tubes and value of shipments amounted to $3.7 billion. For the 102 plants in the 100 metropolitan areas, capacity was 170.0 million tires and tubes; production was 137.0 million tires and tubes; and value of shipments amounted to $2.5 billion.

II. CONTROL OF EMISSIONS

At the present time, insufficient data are available to estimate pollutant emissions from tire and tube production. Even though emissions of carbon black particulates and hydrocarbons are unknown, cost estimates can be based on industry practice which is to control the carbon black with fabric filters to prevent the loss of this valuable material. These devices will enable tire and tube producers to meet the process weight rate regulation. After-burners will readily meet the assumed standard of 90-percent hydrocarbon emission control.

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III. DATA USED IN COST ANALYSIS

The engineering process data required to develop control costs for the rubber industry included estimates for afterburners and fabric filter systems.

A. Afterburner for Tire Cord Dipping Operation

For direct gas-fired systems with no heat exchange, installed cost equals \$25 thousand ± 25 percent [Ref. 1].

The following equation and calculations were used in determining annual costs [Ref. 2]:

$$G = S[195.5 \times 10^{-6} PHK + HF + M]$$

where: $S = 15{,}000$ acfm;
$P = 1''$ water;
$H = 2400$ hours/year (200 days, 12 hours/day of afterburner operation);
$K = \$0.011$/kwh;
$F = \$0.00056$/acfm-hr;
$M = \$0.06$/acfm.

Thus, $G = 1.435S$ or:	\$21,400/yr
Capital charges plus depreciation @ 20%	5,000
Total annual cost:	\$26,400

B. Fabric Filter System

Installed cost of Orlon bags with a continuous air jet cleaning system and a capacity of about 10,000 acfm is estimated to be \$30 thousand [Refs. 1 and 3]. Recovery of carbon black is sufficient to cover the annualized costs of the system.

Since 80 percent of the plants were assumed to already have fabric filter systems, the estimated investment for control of an average model plant is:

\$25,000 (for an afterburner) + 0.20(\$30,000 for a fabric filter) = \$31,000

The following is an example calculation for a sample metropolitan area:

$$\frac{3285\ \text{employees}}{350\ \text{employees/model plant}} = 9\ \text{model plants;}$$

$31,000/plant x 9 plants = $279,000 investment cost;

$26,400/plant x 9 plants = $238,000 annual cost.

No estimate of emissions from this manufacturing process was made due to a lack of emission data. Plants in California are primarily controlled because of an opacity problem and not because of a quantitative emission violation.

IV. CONTROL COST FOR 1967 BASE YEAR

A. Methodology

To determine the air pollution control costs for tire and tube manufacturing plants, a model plant concept was used. This model plant employed 350 persons and produced 825 thousand tires and 206 thousand tubes per year. Many plants do not produce innertubes; however, their control costs would not be much lower since the types of air pollution control equipment required are largely for controlling emissions from tire production.

The model plant was equipped with a direct-fired afterburner to control organic emissions from the tire cord dipping operation, and a fabric filter system for controlling particulate emissions from Banbury mixers. Eighty percent of the plants were assumed to have a fabric filter system, and all plants in California were assumed to be controlled. The installed cost of these control systems in the model plant is $31 thousand. Annualized cost computed only for the afterburner system is $26.4 thousand. The fabric filter system collected valuable raw material[1/] which was returned to the manufacturing operation. It was assumed that the recovery of the raw material would offset the annual charges incurred in owning and operating the baghouse.

[1/] Carbon black at $130 per ton.

In all areas, costs were estimated by determining the number of equivalent model plants within each area (rounded off to the nearest whole number) and multiplying by $31 thousand and $26.4 thousand, respectively, to obtain investment and annual costs.

B. Estimated Costs

The resulting costs, taking into account existing controls and value of recovered carbon black, were totalled for the 100 metropolitan areas and are shown in Table X-1. Control costs on an annualized basis would average approximately $0.01 per tire or tube making capacity when the plan is fully implemented. The investment cost for this level of control would total $2.9 million, with an annual cost of $2.5 million by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

Air pollution control costs were calculated not only for existing capacity (Section IV) but also for increased capacity in the rubber industry beyond the base year of 1967. The projected growth costs were based on the expected ultimate control level of 90.0 percent. The calculations consisted of multiplying the 1967 total investment and annual control costs by the annual growth in capacity to obtain annual investment and annual costs to control the emission from industry growth.

An average annual growth rate of 10.0 percent was used to estimate production increase during the period of 1967 through FY 1975.[2] The capacity estimates, derived from the production estimates, were based on achieving 90 percent utilization of capacity by FY 1975. The cost of controlling the additional capacity are shown in Table X-2. As shown, costs in each year reflect immediate control of the additional capacity at the ultimate control efficiency.

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[2] This estimate was based on Rubber World forecasts.

Table X-1

RUBBER (TIRES AND INNER TUBES) PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]

(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	--	--	--	--	--	--	--	--						
FY71	--	--	--	--	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
FY72	--	--	--	--	--	--	--	--	0.3	0.6	0.9	0.3	0.5	0.6
FY73	--	--	--	--	--	--	--	--	0.6	1.3	2.0	1.0	1.6	2.1
FY74	--	--	--	--	--	--	--	--	0.4	0.8	1.3	1.5	2.3	3.1
FY75	--	--	--	--	--	--	--	--	0.1	0.2	0.3	1.6	2.5	3.4
Total -									1.4	2.9	4.5	4.4	6.9	9.2

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[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Data are not available to estimate emissions and decreases in emissions for this industry.

Table X-2

RUBBER (TIRES AND INNER TUBES) PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]
(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (million tires and tubes per year)	ADDITIONAL PRODUCTION (million tires and tubes per year)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	45	48	--	--	--	--	0.1	0.2	0.3	0.1	0.2	0.3
FY72	58	62	--	--	--	--	0.1	0.3	0.5	0.4	0.6	0.8
FY73	71	76	--	--	--	--	0.2	0.5	0.7	0.7	1.1	1.5
FY74	84	89	--	--	--	--	0.2	0.4	0.6	1.0	1.5	2.1
FY75	97	103	--	--	--	--	0.1	0.2	0.4	1.2	1.9	2.5
Totals -							0.7	1.6	2.5	3.4	5.3	7.2

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Data are not available to estimate emissions in this industry.

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Appendix Y

Secondary Nonferrous Metallurgical Industry

(SIC No. 3341)

Appendix Y

Secondary Nonferrous Metallurgical Industry

I. INTRODUCTION

This industry consists of establishments primarily engaged in recovering nonferrous metals--aluminum, copper, lead, and zinc--from scrap materials. These establishments purchase sorted scrap, recover the metal and often refine it, and finally sell it to other firms that use the metal for further processing.

A substantial quantity of zinc is recovered indirectly through distillation. Also, significant quantities of zinc and lead are recovered by adding zinc- or lead-containing scrap to furnaces preparing copper-based alloys.

In 1967, capacity for the 793 plants in the United States was 2.7 million tons; production reached 2.4 million tons; and value of shipments amounted to $1.6 billion. For the 690 plants in the 100 areas, capacity was 2.4 million tons; production was about 2.2 million tons; and value of shipments was $1.4 billion. Particulate emissions, the major emissions, were 48 thousand tons and 45 thousand tons for the United States and 100 areas, respectively.

Emission of particulates from recovery plants occurs in the melting of scrap and the refining of the molten metal. Scrap metal is invariably contaminated with paint, oils, dirt, and organic materials, which are combined with slag during melting or emitted as particulates in the effluent; oxides of zinc or lead are emitted when those metals are present in the melt.

II. CONTROL OF EMISSIONS

Available estimates indicate that about half of the recovery plants are now controlling emissions. Knowledge of the control devices being used permits the assumption that those plants that do control have an

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efficiency of 95 percent. The resulting national level of control is about 49 percent. Further reduction of particulate emissions from these operations to achieve an overall collection efficiency of 95 percent will be accomplished by FY 1975 with the use of gas-cleaning equipment.

III. DISCUSSION AND EVALUATION OF ENGINEERING DATA USED IN COST ANALYSIS

The basic engineering approach to estimate control costs for the secondary nonferrous metals industry consisted of: (a) an evaluation of production processes within the industry, and (b) an analysis of uncontrolled emission rates and present levels of control.

The processes of the secondary nonferrous metals industry considered in this analysis were brass and bronze melting, secondary aluminum melting, secondary zinc melting, and lead refining. Reverberatory furnaces were assumed for brass and bronze melting and secondary aluminum melting. For secondary zinc melting, kettles were assumed, and a cupola was assumed for lead refining [Ref. 1]. The emissions from the secondary nonferrous metals industry are particulates in the form of dust, fume, and smoke [Ref. 2]. Uncontrolled emission rates for these processes are shown in Table Y-1.

Table Y-1

UNCONTROLLED EMISSION RATES FROM SECONDARY NONFERROUS METALS INDUSTRY

Process	Emission Rate (lb/ton metal charged)
Brass and bronze melting Reverberatory furnace	26.3
Secondary aluminum melting Reverberatory furnace	4.3
Secondary zinc melting Galvanizing kettles	5.3
Lead refining Cupola	300.0

Source: Reference 3.

According to a recent survey [Ref. 4], 51 percent of the primary metal plants control pollutants; this percentage was assumed for the secondary nonferrous metals industry. Plants controlling were further assumed to control at 95-percent efficiency since the equipment normally used to control emissions in this industry includes high energy wet scrubbers, electrostatic precipitators, and fabric filters [Ref. 1]. The resulting average industry level of control was 48.5 percent.

The following data were not used in this analysis, nor were they readily available: process size, gas volume, gas stream temperature, annual hours of operation, and detailed information on control systems. Fortunately, the approach taken in estimating the cost of emission controls in this industry did not require such data since costs per ton of production were available from a recent survey performed by the Department of Commerce [Ref. 1]. Because process size data could not be obtained, it was not possible to determine the efficiency needed to comply with the process weight rate standard. Accordingly, no assumptions as to specific types of control equipment were made, except that current practices which achieve efficiencies of approximately 95 percent will be continued.

IV. CONTROL COSTS FOR 1967 BASE YEAR

A. Methodology

Data obtained from a number of sources were used to identify secondary nonferrous metallurgical plants in the 100 metropolitan areas. Secondary aluminum plant locations were obtained [Ref. 5], and secondary zinc plants were identified [Ref. 6]. Data from Reference 6, supplemented with information from the Bureau of Mines [Ref. 7], were used to compile lists of secondary copper and lead plants in the areas.

Plant capacities for copper, lead, and zinc were estimated indirectly. Production data for the Nation were obtained [Refs. 7 and 8] and peak monthly output was assumed to approximate capacity. Because of the lack of additional information, the assumed capacity was apportioned to each area according to the number of plants in each. The average plant size for each metal was estimated by dividing national capacity by the number of plants in the Nation.

Cost data were abstracted from a publication of the Department of Commerce [Ref. 1], which included investment and annual costs per pound of production. Investment costs were given by type of metal, and annual operating costs were given as an average for all types of metals. Depreciation and capital charges were added to the annual operating cost to obtain total annual costs for each area. Unit costs are shown in Table Y-2.

Table Y-2

EMISSION CONTROL COSTS FOR THE
SECONDARY NONFERROUS METALLURGICAL INDUSTRY

Metals	Average Plant Size (tons/yr)	Investment Cost ($)		Annual Operating Cost[a] ($)	
		Per lb/yr capacity	Per plant	Per lb/yr capacity	Per plant
Brass, bronze, & copper	7,349	0.0095	139,631	0.0012	17,638
Aluminum	4,082	0.0101	82,456	0.0012	9,797
Zinc	268	0.0097	5,199	0.0012	643
Lead	1,418	0.0051	14,464	0.0012	2,413

[a] Annual Operating Cost as reported does not include depreciation and capital-related expenses.

Source: Reference 1.

B. Estimated Costs

The resulting costs were totalled for the 100 metropolitan areas and are shown in Table Y-3. Annual control costs would average approximately $4.96 per ton of capacity when the plan is fully implemented.

Table Y-3

SECONDARY NONFERROUS METALLURGICAL PLANTS

ESTIMATES OF REDUCED EMISSION LEVELS AND ASSOCIATED COSTS[a]
(100 metropolitan areas)

YEAR	EXPECTED EMISSION LEVEL[b] (thousand tons/year)				ASSOCIATED EMISSION CONTROL LEVEL[b] (percent)				CONTROL COSTS (million dollars/year)					
									Investment Cost			Annual Cost		
	Part	SO_x	HC	CO	Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
1967	45	--	--	--	48.5	--	--	--						
FY71	42	--	--	--	52.4	--	--	--	1.4	2.9	4.4	0.5	0.9	1.4
FY72	29	--	--	--	66.7	--	--	--	5.5	11.0	16.5	2.3	4.6	6.9
FY73	13	--	--	--	84.8	--	--	--	6.9	13.9	20.8	4.6	9.2	13.8
FY74	6	--	--	--	93.4	--	--	--	3.3	6.7	10.1	5.7	11.4	17.1
FY75	4	--	--	--	95.0	--	--	--	0.6	1.3	1.9	5.9	11.8	17.7
Total -									17.7	35.8	53.7	19.0	37.9	56.9

[a] Cost estimates are for the control of only those facilities in operation in calendar year 1967. The areas are defined in Appendix B.

[b] For levels of particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks in the table indicates the emission levels meet the applicable regulations (App. A) without additional control.

The emission of particulates would be reduced from 45 thousand tons in 1967 to approximately 4 thousand tons by 1975. The investment cost for this level of control would total $35.8 million, with an annual cost of $11.8 million by FY 1975.

V. CONTROL COSTS RESULTING FROM GROWTH

An average growth rate of 5 percent per year was used to estimate growth in production from 1967 to FY 1975 [Ref. 9]. The capacity estimates were derived from the production estimates and were based on achieving 90-percent utilization of capacity by FY 1975. Cost estimates for controlling particulate emissions from the projected additional capacity are shown in Table Y-4. By 1975, from the 1967 capacity plus the capacity added subsequent to 1967, emissions of particulates in the 100 areas would reach 65 thousand tons without the act in effect. With the act in effect, emissions would be reduced to 4 thousand tons.

Table Y-4

SECONDARY NONFERROUS METALLURGICAL PLANTS

ESTIMATED COST OF CONTROLLING POLLUTANT EMISSIONS FROM SOURCES ADDED AFTER 1967[a]

(100 metropolitan areas)

FISCAL YEAR	ADDED CAPACITY (thousand tons/yr)	ADDITIONAL PRODUCTION (thousand tons/yr)	EMISSION LEVEL[b] (thousand tons/year)				CONTROL COSTS (million dollars/year)					
							INVESTMENT COST			ANNUAL COST		
			Part	SO_x	HC	CO	Lower Limit	Expected	Upper Limit	Lower Limit	Expected	Upper Limit
FY71	432	377	1	<1	--	--	1.2	2.5	3.7	0.6	1.2	1.8
FY72	556	485	1	<1	--	--	1.7	3.4	5.2	1.4	2.9	4.4
FY73	679	593	2	1	--	--	2.5	5.0	7.5	2.3	4.6	6.9
FY74	803	701	2	1	--	--	2.3	4.7	7.1	2.8	5.7	8.5
FY75	926	809	3	1	--	--	1.5	3.1	4.7	3.3	6.6	9.9
Totals -							9.2	18.7	28.2	10.4	21.0	31.5

[a] These costs are for new facilities which are assumed to be constructed to meet applicable regulations (App. A); areas are defined in Appendix B.

[b] Particulates (Part.), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO). Blanks indicate the emissions need no control.

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Appendix Z

Coking Industry
(SIC No. 2999)

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Appendix Z

Coking Industry

I. INTRODUCTION

The coking industry was included among the industrial sources considered in this research since it was known to be a significant source of particulates and sulfur oxides. However, since acceptable methods of controlling these emissions are not available currently,[1/] control cost estimates were not made for this industry. The data obtained on the industry and its emissions are presented in this appendix.

Coke is a major fuel in the metallurgical industry and a process material in some chemical operations. In addition, miscellaneous products such as briquettes made from a variety of fuels such as charcoal, sawdust, and peat, are included in the category of coke. However, the primary raw materials from which coke is produced are coal and petroleum residuals. A major portion of coke from coal is produced by the iron and steel industry and coke from petroleum is produced by petroleum refineries.

During the period 1963-1967, the national average annual production of metallurgical coke was 63 million tons and miscellaneous coke production was 3 million tons [Ref. 1]. The annual value of shipments for metallurgical coke and miscellaneous coke for 1967 was $935 million and $75 million, respectively [Refs. 1,2,3,4, and 5]. Annual particulate emission from the coking industry in the United States amounted to 43 thousand tons and sulfur oxide emissions 430 thousand tons.

II. CONTROL OF EMISSIONS

Beehive and by-product slot oven coking were the processes considered in the analysis. Miscellaneous coke is produced in both beehive and by-product ovens while metallurgical coke is produced almost entirely in by-

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[1/] The European coking industry has developed innovative approaches to the control of emissions from coke ovens. To date, however, no method has met with acceptance by American industry.

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product ovens. The unit operations which result in pollutant emissions are shown for both processes in Table Z-1.

Table Z-1

EMISSIONS FROM BEEHIVE AND BY-PRODUCT OVENS

Operation	Process Emissions	
	Beehive Oven	By-product Oven
Coal handling & charging	Dust, tars, gas	Dust, tars, gas
Coking with gas combustion	Dust, tars, H_2S,CO,SO_2	*
Coking	*	Minor leaks
Pushing	*	Dust, tars, H_2S
Quenching	Dust, CO, CH_4	Dust, CO, CH_4
Discharging & coke handling	Dust	Dust
Coke gas combustion	*	SO_2

* Not applicable.

Beehive coke ovens are not controlled, but some of the operations in by-product ovens are. The percent of by-product ovens controlled and the control efficiency achieved are given in Table Z-2. Particulate emissions from coal handling and from charging and quenching are reduced by steam jet ejectors in gas lines and baffles in towers, respectively. Sulfur compound emissions from coke gas combustion may be reduced by coke gas scrubbers (H_2S and Claus sulfur recovery units). Feasible methods for obtaining adequate control of all operations have not been developed.

Table Z-2

LEVELS OF CONTROL FOR BY-PRODUCT COKE OVENS

Operation	Percent Using Control Techniques	Average Efficiency (percent)
Coal handling	50	90
Charging	50	--
Coking	--	--
Pushing	--	--
Quenching	10	90
Coke gas combustion	10	90

-- Unknown

Source: Reference 6.

III. ENGINEERING ANALYSIS

Data obtained for the two coking processes are described in this section.

A typical beehive oven charge is 6.5 tons of coal, while the typical charge for a by-product oven is 18 tons [Ref. 7]. Beehive ovens yield only 60 percent of the charge as coke and volatilize one-third more material than by-product ovens. Beehive volatiles burn at the vent during coking at a temperature of 2600° F. Combustion of by-product oven gas at 2000° F oxidizes H_2S to SO_2 [Ref. 8]. The processes are batch operated and tend to emit large quantities of pollutants in a very short time period. They were assumed to operate 8500 hours per year.

Uncontrolled emission rates for coking operations by process are shown in Table Z-3.

Table Z-3

UNCONTROLLED EMISSION RATES FOR COKING OPERATIONS

Operation	Beehive Oven	By-product Oven
Coal handling & charging	1 lb dust/ton coal charged	1 lb dust/ton coal charged
Coking	*	Negligible
Coking with gas combustion	50% of sulfur in coal as SO_2	*
Pushing	*	Unknown
Quenching	0.33 lb dust/ton coal charged	0.33 lb dust/ton coal charged
Coke gas combustion	*	10 lb SO_2/ton coal charged (assumes a coal of 0.5% S content, releases 50% of S in coking)

* Not Applicable.

Source: References 7, 8, and 9.

The estimated gas volumes to be handled by air pollution control systems for beehive and by-product ovens are shown in Table Z-4 and the assumptions employed to make the estimates are discussed in the following paragraphs.

Table Z-4

GAS VOLUMES FOR COKING OPERATIONS

Operation	Beehive Oven (10^3 acf/ton coal charged)	By-product Oven (10^3 acf/ton coal charged)
Coking	400	*
Quenching	50	50
Coke oven gas combustion	*	420

* Not applicable.

For beehive ovens, it was assumed that the coal contains 20 percent total moisture [Ref. 10], that coking produces a 60 percent yield based on coal charged, and that complete combustion takes place at the vent. The volumes of nitrogen, equivalent to the oxygen used, are included in the calculation. The exit temperature is 2600° F, and standard temperature is 60° F. The coking gases are those evolved at 2600° F during an 18 hour interval. The quenching gases are evolved at 150° F during a 2 minute interval.

For by-product ovens, it was assumed that approximately 11,000 scf of coke oven gas is produced per ton of coal charged [Refs. 11 and 12]. It was further assumed that all of this gas is consumed (primarily to heat the by-product ovens) with 50 percent excess combustion air and that the equivalent nitrogen is included in the calculated volume. The stack exit temperature was assumed to be 2200° F and the gases are evolved during an 18 hour interval. The quench gases have the same evolution time and temperatures as the beehive ovens.

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Appendix AA

Plastics Industry
(SIC No. 2821)

Appendix AA

Plastics Industry

I. INTRODUCTION

The plastics industry was included among the sources considered in this research. However, an analysis of the manufacturing processes used in this industry showed that the emissions from the industry are of minor significance. Accordingly, control cost estimates were not prepared for the plastics industry. The information collected is presented below.

The plastics industry consists of those establishments primarily manufacturing plastic resins. Non-chemical firms who buy resin for their use and chemical or petro-chemical plants that only manufacture the basic chemicals (monomers) from which the resin is made are classified elsewhere. Plastic resins are used to make fabricated products such as plastic milk containers, film, and sheets. Currently, the three largest selling plastics are polyethylene, polystyrene, and polyvinyl chloride.

In 1967, the national capacity of this industry was 8 million tons of all plastic resins [Ref. 1]. The 1963 through 1967 average annual production for the United States was 5.14 million tons, and the average annual value added was $1.49 billion for the same period [Refs. 2,3,4,5,6, and 7]. The 1967 value of shipments was $3.5 billion [Ref. 7]. In 1967, there were 661 plants, 341 of which had 20 or more employees [Ref. 7]. By 1968, the total number of plants had grown to 675 [Ref. 8].

Data for estimating emissions were not available. However, Lund [Ref. 9] reported that 77 percent of plants reporting in a survey of the rubber and plastics industry had unsolved air pollution problems, with 26 percent of emissions not under control. However, it is probable that most of the uncontrolled emissions reported were in the rubber industry. Pollutants related to plastics manufacture specifically identified in the survey as uncontrolled were resin fumes from treating ovens and phenolic odors.

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II. CONTROL OF EMISSIONS

Odorous gas emissions constitute the primary pollution problem associated with the plastics industry, with other emissions very minor. However, there are no data available to quantify odorous gas emissions. In general, it appears that materials are handled in gas-tight containers or vessels at all stages during production. To maximize recovery of materials, control equipment is incorporated into the production system and as such is not considered air pollution control equipment. This equipment includes floating roofs on tanks containing volatile materials, vapor recovery systems (absorption or condensation), and recovery systems on vacuum exhaust and purge lines. Since the processes are operated at very high pressures and are not vented to the atmosphere, pollutant emissions result from leaks or the opening of vessels to add materials. Very little pollutant, apparently, is discharged to the atmosphere as a normal part of the production process. Considerable additional data will be required to estimate emissions and calculate the degree of control needed, if any.

III. ENGINEERING ANALYSIS

The manufacture of most plastics begins with a catalyzed polymerization or linking of the basic compound (monomer), usually a gas or liquid, into a high molecular weight non-crystalline solid. Washing and drying follow the polymerization step. The final molding or forming step to make plastic products is usually done in a separate operation, often at a different location or by a resin customer.

Detailed descriptions of the individual manufacturing processes are available but do not provide information on the air pollution aspects. Most plastics are polymerized or otherwise reacted in a jacketed, indirectly heated, stainless steel vessel, which is completely enclosed, equipped with a stirring mechanism, and generally contains an integral reflux condenser. Since most of the reactions are exothermic, cooling coils are usually required.

Some resins, such as the phenolics, require that the kettle be under vacuum during part of the cycle. Vacuum is provided either by a pump or by a steam or water-jet ejector. Moreover, for some reactions, e.g., polyvinyl chloride, the vessel must be capable of being operated under pressure to keep the normally gaseous monomer in a liquid state. The sizes of resin-processing kettles vary from a few hundred gallons to several thousand gallons capacity.

Because of the many types of raw materials (gaseous, liquid, and solid), storage facilities vary--ethylene, a gas, is handled as such; vinyl chloride, a gas at standard conditions, is liquified easily under pressure, and it is stored, therefore, as a liquid in a pressurized vessel. Most of the other liquid monomers do not present any particular storage problems. Styrene and vinyl chloride, however, must be stored in an inert atmosphere to prevent premature polymerization. Some of the more volatile materials are stored in refrigerated tanks to control vapor loss. Some of the materials have strong odors, and care must be taken to prevent emission of odors to the atmosphere. Solids, such as phthalic anhydride, are usually packaged and stored in air-tight bags or fiber drums.

Treatment of the resin after polymerization varies with the proposed use. Resins for moldings are dried and crushed or ground into molding powder. Resins, such as the alkyd resins used for protective coatings are normally transferred to an agitated thinning tank where they are thinned with a solvent. Storage is in large steel tanks equipped with water-cooled condensers to prevent loss of solvent to the atmosphere. Still other resins are stored in latex (dispersion) form as they come from the kettle.

Possible major air pollutant emissions in plastics manufacturing are emissions of raw materials or monomer to the atmosphere, emissions of solvent or other volatile liquids during the reaction, emissions of sublimed solids such as phthalic anhydride in alykd production, and emissions of solvents during storage and handling of thinned resins. Table AA-1 lists the most probable types and sources of air pollutants from various plastic-manufacturing operations and how the pollutants may be controlled.

Table AA-1

PLASTICS MANUFACTURING EMISSIONS, SOURCES, AND CONTROL

Plastic	Emission	Source	Control
Phenolic	Aldehydes	Storage, leaks, condenser outlets, vacuum pumps	Additional condenser capacity, maintenance
Amino	Aldehydes	Storage and leaks	Maintenance
Polyesters	Oil cooking odors, phthalic anhydride, solvents	Cooker discharge, condenser discharge	Condensers, scrubbers
Polyvinyl Acetate	Odors, solvents	Storage, condenser outlets	Additional condenser capacity
Polystyrene	Odors	Leaks	Maintenance
Polyurethane	Tolylene diisocyanate	Product	Dilute

Source: Reference 10.

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Appendix BB

Rendering Industry
(SIC No. 2094)

Appendix BB

Rendering Industry

I. INTRODUCTION

The rendering industry was included in the original list of sources considered. However, since odors are the primary air pollutant emitted by the rendering industry and because odors were not included in this research, this source was deleted from the study; no control cost estimates were made. However, the results obtained in the preliminary analysis of this source are presented herein.

Rendering is the process through which fish and animal matter are reduced by heating with steam to separate their fat and oil content. The 1967 U.S. capacity was assumed to be approximated by the 1963 production of 5,290,420 tons [Ref. 1]. The corresponding 1967 approximation of the 100 metropolitan area capacity was 3,545 thousand tons. In 1967 there were approximately 931 rendering plants in the United States with an average annual production of 4,774,600 tons for the years 1961 through 1966 [Refs. 2 and 3]. Estimated production for the same period for the 100 metropolitan areas was 3,183,500 tons. Production in 1968 for the United States consisted of 306.5 thousand tons of fish meal [Ref. 3]. Annual value of shipments for the United States averaged $621 million for the years 1963 through 1967 [Refs. 1,4,5, and 6]. Estimated value of shipments for the same period for the 100 metropolitan areas was $424 million. Assuming feedstock containing 50 percent moisture, forty percent evaporation, and dry rendering, the potential emissions for the Nation would be $8.82 (10)^{15}$ odor units per year.

Rendering plants vary in the type of feedstock rendered, e.g., fish and poultry. The distribution of rendering plants by type of feedstock and operations is shown in Table BB-1.

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Table BB-1

DISTRIBUTION OF RENDERING PLANTS IN THE UNITED STATES

Type	Number of Plants	Percent of Total
Independent renderers (from butchers, stockyard deaths, dead animals, etc.)	395	42
Livestock slaughter-house renderers	381	41
Marine (fish) renderers	104	11
Poultry slaughter house renderers	36	4
Blenders (receive, mix, and sell)	15	2

Source: References 3, 7, and 8.

II. CONTROL OF EMISSIONS

Air pollutant emissions from rendering plants consist almost entirely of organic compounds characterized by unpleasant odors. Some of the odors result from the handling and storage of material, but most result from the operation of cookers at relatively high temperatures. Expert opinion holds that approximately 50 percent of plants have some control but only 20 percent have effective control. Control efficiency probably ranges from 50 to 99 percent.

Control of these odors can be accomplished by the use of incinerators in the exhaust gas stream from the cookers, with or without condensers. Incineration at 1200° F for 0.3 seconds destroys most odorous compounds. With condensers, removal efficiencies above 99.9 percent are possible [Ref. 9]. Good sanitation and housekeeping can prevent most odor emissions resulting from storage and handling processes.

III. ENGINEERING ANALYSIS

Of the two types of rendering processes, dry and wet, the former is by far the most widely used. For this reason the model plant [1] described below is of the dry type.

The model continuous dry rendering plant produces 120 tons of finished product per day from 224 tons of raw feedstock, based on 24 hours of operation. The model plant consists of seven 8 thousand pound capacity cookers that require three hours per batch. The annual production of the plant is 37,440 tons, assuming a six-day week and 52 weeks per year. Annual hours of operation thus amount to 7488, assuming a 24-hour day.

The uncontrolled exit gas volume from the plant is 4 million cubic feet per day at 60° F or 192 thousand cubic feet per hour at 140° F [Ref. 10]. The gas stream temperature is 212° F at the cooker, 140° F at the condenser, and 1200° F at the afterburner [Ref. 10]. Ninety-five percent of the exhaust gas volume is steam which may be completely reduced by condensation [Ref. 8]. Uncontrolled annual emissions amount to 6.24 (10^{13}) odor units per year, based on 312 days of operation. Odorous compounds can be destroyed by heating to 1200° F for 0.3 seconds.

The control system selected consists of an afterburner and an interceptor followed by an air-cooled surface condenser. Natural gas would be required to fuel the afterburner.

The afterburner would be designed for a maximum flow rate of 515 cubic feet of natural gas per hour and a maximum exhaust gas flow rate of 320 cfm at 140° F. The dimensions of the afterburner are: throat diameter, 13.4 inches; combustion chamber diameter, 16 inches; and combustion chamber length, 4 feet. This control system reportedly will achieve 99.9 percent odor removal [Ref. 9]. The low, medium, and high investment costs for the control system described above are $150 thousand, $225 thousand, and $450 thousand, respectively. The corresponding annual costs are $30 thousand, $50 thousand, and $70 thousand, respectively.

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[1] The available data were insufficient to construct a continuous relationship between gas volume and process size.

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Appendix CC

Soap and Detergent Industry
(SIC No. 2841)

Appendix CC

Soap and Detergent Industry

I. INTRODUCTION

The soap and detergent industry was one of the pollutant sources originally selected for analysis. However, a preliminary study indicated that particulate emissions from this industry did not exceed the assumed emission standard and odors were subsequently deleted from consideration. Accordingly, control cost estimates were not prepared for the soap and detergent industry. The findings of the preliminary study are reported in this appendix.

The soap and detergent industry includes the manufacture of soap (granulated, liquid, cake, flaked and chip) and detergents (synthetic organic and inorganic alkaline). In 1968, the national annual capacities were 1,150 million pounds and 5,630 million pounds of soap and detergent respectively [Refs. 1 and 2]. The average annual production for the period 1964 through 1968 was 1,140 million pounds of soap and 5,130 million pounds of detergent [Refs. 1 and 2]. Also for the period 1964 through 1968, the average annual value of shipments was $432 million for soap and $1,014 million for detergent [Refs. 1 and 2].

In 1968 there were 1,066 soap and detergent plants in the United States [Ref. 3]. Particulate emissions from these plants ranged from 0.03 to 0.15 percent of total soap and detergent production [Ref. 4]. Spray tower exhaust may contain 4 to 5 odor units per scf [Ref. 4].

II. CONTROL OF EMISSIONS

Emissions from the soap and detergent industry consist primarily of ordors and particulates entrained in the spray drier. Cyclones, often in combination with other types of particle collection equipment, are used throughout the industry to control particulate emissions. The control

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efficiencies achieved with cyclones, cyclones and spray chambers, cyclones and packed chambers, and cyclones and venturi scrubbers are 90.0, 95.0, 96.6, and 98.4 percent, respectively [Refs. 5 and 6]. Cyclones are considered to be process equipment rather than air pollution control equipment. The extent to which odors are controlled in this industry is unknown.

III. ENGINEERING ANALYSIS

The data and information obtained in the preliminary study of the soap and detergent industry are presented below.

Production rates in this industry vary from 100 to 10,000 pounds per hour and the exhaust gas volume is approximately 30 standard cubic feet (scf) per pound of product. The temperature of the exhaust gas stream ranges from 150° to 250° F [Ref. 4]. Control systems, if applied, would range in size from 3 thousand to 300 thousand scfh. Fifty percent of emitted particles are less than 50 microns in diameter [Ref. 4].

The analysis which led to the conclusion that particulate emissions do not exceed the assumed emission standard was based largely on data presented by Phelps [Ref. 4]. This analysis is described in the following paragraphs.

It was known that the resultant emissions following primary cyclones amounted to 0.01 to 0.3 grains per cubic foot. It remained then to calculate volumetric gas flow rates as a function of production. This volume calculation was made as follows: (a) the drier was assumed to operate on heated ambient air containing 0.0009 pounds of H_2O per pound of dry air (dew point = 54° F) and to exhaust air at average dry bulb and wet bulb temperatures of 200° and 135° F, respectively [Ref. 4]--corresponding to a water content of 0.131 pounds of H_2O per pound of dry air [Ref. 7]--and (b) hot liquid soap detergent was assumed to contain 36 percent H_2O before drying and 15 percent after [Ref. 8].

A material balance on the drier showed that 100 pounds of wet soap containing 36 pounds of H_2O requires 172 pounds of ambient air (or 3000 ft^3) to dry the soap. Thus, 30 standard scf air per pound of product is required for drying. It should be noted that the wide range of wet bulb temperatures given for the drier exhaust (120° to 150° F) results in a correspondingly wide range around the estimate of the required air volume per pound of product. However, it is clearly not feasible to operate the drier with the exhaust gas very close to the dew point; therefore, the assumption of a dew point of 135° F results in a reasonable but conservative estimate (30 scf air per pound of product). Using the 30 scf estimate and the emission factors stated above, it can be shown that this results in emissions ranging from 0.03 to 0.15 percent of production.

For particulates, the process weight rate standard was assumed. The process weight rate factor was assumed to be 1.0 [Ref. 8], i.e., 1 pound of raw material produces 1.00 pound of product. Using the highest value for emissions (0.15 percent of production), all the listed U.S. plants, except the two largest (200 to 300 million and 300 to 400 million pounds/yr), comply with the standard without additional control. Because it appeared that only two plants could likely exceed the standard (and minimal secondary control, e.g., spray chambers would adequately control these), it was concluded that additional controls were not needed for particulate emissions from this industry. However, it is not known whether these two plants have secondary controls.

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